A conceptual report

Transportation in the Texas Coastal Zone

Texas ~~State~~ Division of Planning Coordination

Division of Planning Coordination
Office of the Governor

COASTAL RESOURCES MANAGEMENT PROGRAM

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TRANSPORTATION IN THE TEXAS COASTAL ZONE

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INTERAGENCY COUNCIL ON NATURAL RESOURCES
AND THE ENVIRONMENT
STATE OF TEXAS

by

TRANSPORTATION PLANNING PROGRAM
TEXAS TRANSPORTATION INSTITUTE
TEXAS A&M UNIVERSITY

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TEXAS TRANSPORTATION INSTITUTE

This report prepared by

TEXAS TRANSPORTATION INSTITUTE
TEXAS A&M UNIVERSITY
Ronald W. Holder, Project Director

Contributions by

Jack T. Lamkin, Assistant Research Economist
Dennis L. Christiansen, Research Assistant
William R. Lowery, Research Assistant
Vergil G. Stover, Program Manager

Prepared for

THE INTERAGENCY COUNCIL ON NATURAL RESOURCES AND THE ENVIRONMENT

Staff Support Provided by the Division of Planning Coordination, Ed Grisham, Director.

Joe B. Harris - Coordinator of Natural Resources
Joe C. Moseley II - Project Director, Coastal Resources Management Program
Linda Johnston - Reports Editor
Charles Cooke - Planning Analyst

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INTRODUCTION

The Coastal Zone of Texas contains the most diverse grouping of valuable natural resources in the state. Because many of these resources are irreplaceable assets belonging to the people of Texas, they should be conserved, developed, and preserved in accordance with the goals of the state. Inevitable pressures of urban, commercial, industrial, and agricultural growth are causing a general degradation of the Coastal Zone environment which will worsen unless steps are taken by state and local governments to safeguard this valuable resource area. Thus, the 61st Legislature of Texas authorized the establishment of the Coastal Resources Management Program. This transportation study is one of several studies sponsored by that program in an effort to identify the actions required to safeguard the environmental integrity of the Coastal Zone for future generations of Texans while fully utilizing coastal resources (1)*.

DESCRIPTION OF AREA

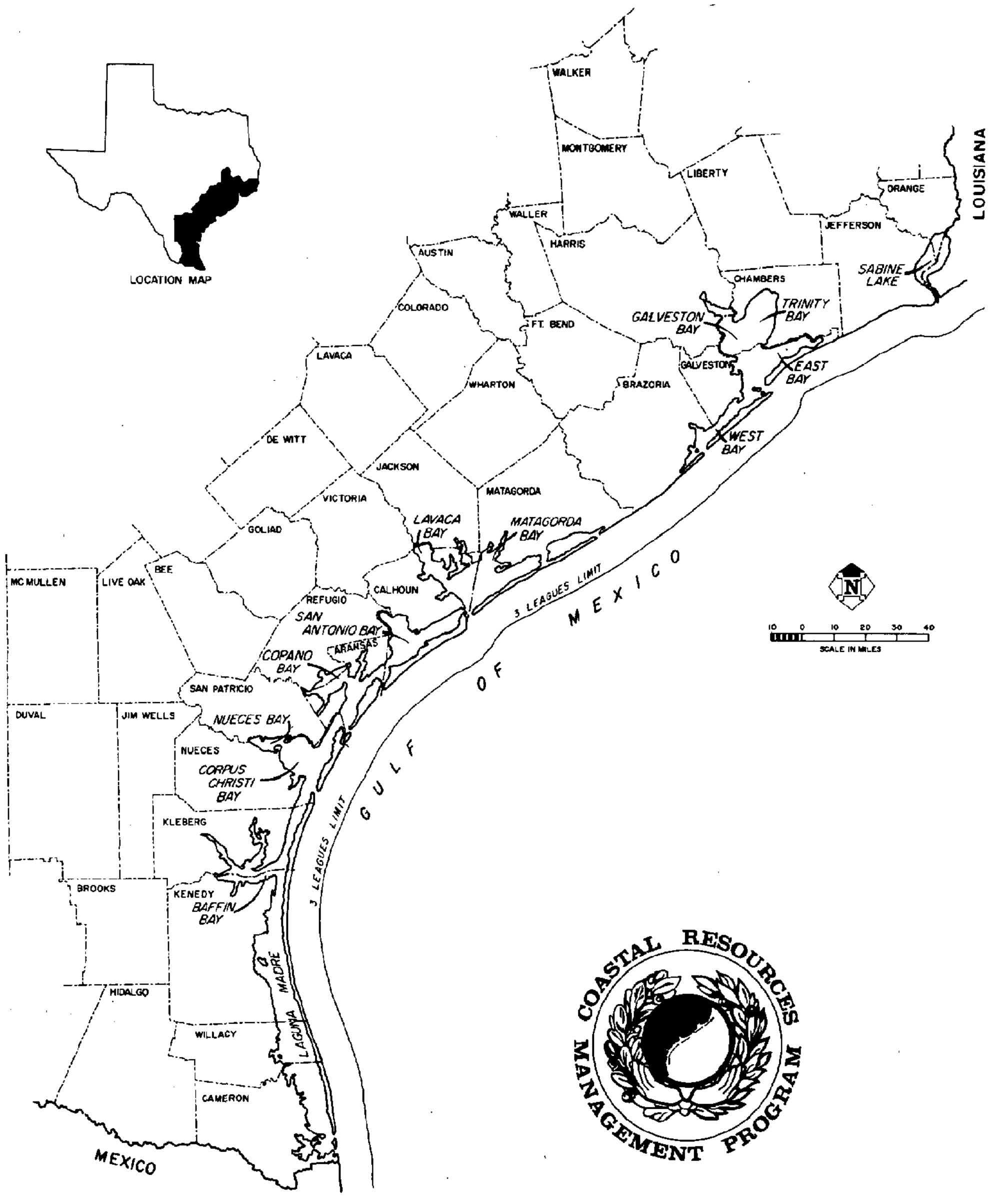
The Coastal Zone of Texas, as defined for this study covers the 36-county area shown in Figure 1 and extends a distance of 10.35 miles into the Gulf. Although the Coastal Zone was defined to include all of the Planning Regions in Texas which have one or more counties bordering the Gulf of Mexico, it roughly delineates the coastal plains of Texas. These 36 counties contain some 33,334 square miles of land area – about one-eighth of the state's total. Approximately 80 percent of this land is in private ownership while the state owns about 16 percent and federal and local governments own about two percent each (2).

The Coastal Zone includes about 760 square miles of marshlands and some 2100 square miles of bays and estuaries which contain numerous valuable but extremely vulnerable natural resources. These near-shore waters along the Texas coast constitute the major spawning and nursery areas for more than 70 percent of the fish population in the Gulf of Mexico (3). There are about 1800 miles of waterfront along the Texas coast (some 1400 miles front on bays and estuaries while about 375 miles front on the Gulf) of which more than 1000 miles are considered to be suitable for recreational uses (4). In 1969, almost three million tourists visited the Gulf coast of Texas, and they spent more than $190 million (1). Yet, much of the Texas coastline is still relatively undeveloped.

The area is rich in natural resources – notably oil, natural gas, salt, sulfur, shell, and agricultural land. The direct value of minerals

*Denotes reference number listed at end of this report.

FIGURE I-1 THE COASTAL ZONE OF TEXAS



The Coastal Zone of Texas contains the most diverse grouping of valuable natural resources in the State. Three and a half million persons presently live within the Coastal Zone and the population is expected to double by the year 2000 AD. Transportation is an essential element of its development and the demand for transportation is increasing much faster than population. Careful planning and appropriate action by the State is required if the projected growth is to be accommodated with minimum impact upon the environment.

produced in the Coastal Zone annually total more than $1.5 billion – more than one-fourth of the state's total (5). The Texas Coastal Zone contains almost half of the nation's petrochemical industry and about one-fourth of its refining capability (1). Several of the state's most productive agricultural areas, including the fertile Rio Grande Valley, are located within the Coastal Zone.

GROWTH TRENDS

Three and a half million persons, about one-third of the state's population, lived in the Coastal Zone in 1970 (6). It is one of the fastest growing areas of the state. The population of the Coastal Zone increased from 1.5 million in 1940 to 3.5 million in 1970. In other words, it more than doubled in the last 30 years. Recent population estimates for Texas (7) project an increase from 3.5 million in 1970 to 6.0 million in 1990 for the 36 counties in the Coastal Zone. If this expected growth rate actually occurs and the rate continues through the year 2000 AD, the population of the Coastal Zone will double again during the next 30 years (1970-2000 AD).

In 1970, 84 percent of the population of the Coastal Zone lived in urban areas, and almost all of the projected growth is expected to occur in urban areas. If this urban growth occurs at average population densities that are typical for cities in the Coastal Zone, and other Texas cities, urban development will double in the next 30 years. Fortunately, most of the existing urban development is concentrated in cities occupying no more than three percent of the total land area. Thus most of the Coastal Zone, with its rich natural resources, is relatively unspoiled; however, the anticipated growth will place great demands upon the natural resources and may generate significant environmental changes.

Historically, the demand for transportation services has grown much faster than the population. During the past twenty years, the nation's population has increased by about 33 percent while intercity freight movement has increased more than 50 percent and intercity passenger travel has more than doubled (8). Recent studies of urban travel characteristics in Texas cities have revealed that the number of daily auto trips per person has increased about 50 percent over the past ten years. Thus, the demand for transportation in the Coastal Zone could more than triple in the next 30 years.

TRANSPORTATION SYSTEM

The transportation system serving the Texas Coastal Zone includes major elements of every existing mode of transportation. Eleven ports serve ocean-going ships, and the Gulf Intracoastal Waterway connects the

Texas coast to an extensive inland waterway system serving the heartland of the nation. Eight airports in the Coastal Zone are served by scheduled air carriers. The area is crisscrossed by numerous pipelines carrying crude oil and petroleum products. An extensive network of almost 3000 miles of main-line railroads serves the region and connects it to the rest of the state and the nation. About 12,000 miles of highways form the backbone of the total transportation system serving the Coastal Zone.

Some of these transportation facilities are presently operating near capacity while others are not utilized to more than a fraction of their ultimate capacity. Thus, the problem is to identify ways to serve the rapidly growing demand for transportation with minimum costs and minimum detrimental effects upon the environment. This implies a more effective utilization of the total transportation system serving the Coastal Zone.

OBJECTIVES OF STUDY

This study constitutes an inital planning study, at the macroscopic level, for a total transportation system to serve the Texas Coastal Zone. The primary objectives are:

(1) To identify broad alternatives for future development and transportation systems;

(2) To evaluate the probable consequences of each major alternative;

(3) To identify critical relationships between urban form, land use, and transportation systems;

(4) To outline general guidelines that can be used to insure compatible developments in the future; and

(5) To identify specific actions that the state can take to help insure an effective future transportation system which will have minimum impact upon the environment.

Since this is a transportation planning study at the macroscopic level, considering broad alternatives for future development, it does not replace the numerous detailed planning studies for each transportation mode, but rather, it should complement them.

SUMMARY OF REPORT

GENERAL TRANSPORTATION CONSIDERATIONS

URBAN TRANSPORTATION

Total urban population of the Coastal Zone may double before the year 2000 A.D.; therefore, careful planning is essential in order to accommodate this growth in a manner that yields desirable urban environments and effective transportation systems. A recognition of the interrelationships between land uses and compatible forms of transportation is the key to proper urban planning. Land use plans and transportation plans cannot be developed separately because they are, and must be, one in the same.

A "balanced transportation" system can only be achieved through a recognition of the mutual dependence of urban land use and mode of transportation. Single family houses cannot be served economically by rail rapid transit nor can high-rise apartments be served adequately by automobiles alone. Once a city chooses a desired type of land development, it has automatically limited the types of transportation systems that can be used effectively.

> *Note - A more complete summary of this report is provided by the information contained in the various figures and tables together with their captions.*

The integral relationships between land use and transportation can be illustrated by a comparison of urban forms required for two totally different types of transportation systems. Automobiles on the one hand and rail rapid transit on the other constitute both ends of today's urban transportation spectrum. Cities could be designed to be served adequately by either mode of transportation, but they would require totally different urban forms and would result in significantly different lifestyles.

If two such cities were properly designed, they would both have pleasant urban environments, and each city would have some distinct advantages and disadvantages relative to the other. In the Auto-City, people would live in single-family houses and have cars available for all urban and intercity trips. Residents of the RRT-City would live in high-rise apartment buildings; walk to the grocery store, transit station, schools, and recreational facilities; and use rail rapid transit for longer urban trips. Persons who could not walk long distances would be severely disadvantaged in the RRT-City just as the non-driver is disadvantaged in the Auto-City.

The total investment in transportation would be somewhat less in the RRT-City, but housing costs would be significantly higher. The total annual cost per person for both transportation and housing would be slightly higher in the RRT-City. However, the types of urban developments required for total dependence on either the automobile or rail rapid transit are so drastically different that it is not surprising that no city has yet been able to successfully integrate both modes into a single urban transportation system.

Since most of their residents live in single-family dwelling units, Coastal Zone cities have developed at relatively low average densities that can best be served by the automobile operating on a well designed system of arterial streets and freeways. Despite the expected rapid urban growth in the future, existing developments will not be abandoned; therefore, future urban transportation systems must be compatible with existing automobile-based systems. Even so, the larger cities may have to rely more heavily on some form of mass transportation.

Future developments might be shaped to modify existing urban forms so that mass transportation modes can be used effectively. Conceptual urban forms that might be considered include high-density corridors, transportation terminals, or multiple focal points. Regardless of the concept selected, Coastal Zone cities must apply careful planning and effective land management if the net result is to be an effective balance between urban form and the transportation system.

Several modes of urban transportation are presently available for utilization in the movement of people including the automobile, local bus, bus rapid transit, personal rapid transit, skybus, and rail rapid transit. The automobile is the most flexible mode since it can be operated independently on the extensive street and freeway system. Rail rapid transit is the least flexible mode since it must operate only on its own fixed way and normally follows a fixed schedule. The level of flexibility of the other modes varies between these two extremes.

Bus rapid transit systems require less total investment than other modes of mass transportation, and they offer the highest capacity for passenger movement along a single route. When peak-hour transit demands increase beyond 20,000 passengers in a single corridor, the total cost of rail systems become competitive with bus systems. However, none of the urban corridors in the Coastal Zone are expected to have such high levels of demand during the next 30 years unless drastic changes in urban form occur.

INTERCITY TRANSPORTATION

Approximately 90% of intercity passenger travel in the nation is by private automobile. The automobile offers a level of convenience and degree of flexibility that is unattainable with any form of common carriage. When only out-of-pocket costs are considered, automobiles are the lowest cost mode for trips requiring no more than one day of travel. However, bus costs are considerably lower than fully-distributed costs for automobiles.

Trends in intercity common carriage show that rail travel is being replaced by air travel while bus travel has remained relatively constant. This might indicate a demand for only two types of intercity carriage: one that offers the best level of service and one that offers the lowest price. However, as passenger demands increase in the Coastal Zone, high speed rail service could possible replace airlines as the preferred mode for relatively short intercity trips.

Each mode presently used to transport goods between cities (rail, pipeline, motor truck, air cargo, inland water, and ocean transport) possesses inherent characteristics that make it particularly well suited for certain types of traffic. Motor trucks and air cargo offer a high level of service that is attractive for high-valued goods. The other modes are well suited for bulk carriage since their costs are much lower than trucks and air cargo.

The demand for transportation services has historically grown much faster than population so the damand for intercity goods movement in the Coastal Zone could triple in the next 30 years. Thus, relative capacities of various modes for moving goods is an important consideration for planning purposes. The two modes of water transportation, barges and ships, offer much higher capacities than the other modes. A barge canal similar to the Gulf Intracoastal Waterway in Texas can handle as much as 1,000,000 tons/day; however, the locks in the Louisiana segment of the canal can only pass about one fifth of that volume. Typical capacities of railroads, pipelines, all-cargo airports, and exclusive truck highways are only about one-tenth the capacity of barge canals.

ENVIRONMENTAL CONSIDERATIONS

Mechanized transportation is more than just a convenience for man - it is essential for the survival of his society. Unfortunatley, all modes of transportation must have some impact upon the environment; however, the amount of environmental damage can be minimized. The first step toward improvement is a definition of the major areas of environmental concern. Air quality, water quality, noise, waste heat, drainage, and land-use patterns appear to be justifyable areas of major concern. Other environmental considerations such as visual pollution, litter, and junk yards are valid concerns, but they are not a direct result of the construction or operation of transportation modes.

Most environmental studies have pointed to the highway mode as the most serious polluter of the environment; however, this is partly due to the relative usage of modes. Highways provide for more than 90% of all person movement and 50% of all goods movement in the nation. A comparison of the relative potential of environmental impacts of the various modes operating at the same level of activity shows that most of them are about equal. Pipeline appears to be the only mode that has a significantly lower potential. Corrective actions are already being taken to reduce the severity of most of these environmental impacts so transportation systems of the future will be more compatible with the environment.

The automobile is the most visible source of air pollution to the general public; therefore, it has been the object of much criticism. Some people have proposed eliminating all automobiles, or at least outlawing the internal combustion engine. However, no propulsion system available today can achieve better thermal efficiencies over the broad range of operating conditions required of the automobile. Reciprocating steam engines, steam turbines, gas turbines, and electrical batteries are all being evaluated as possible prime movers, but none of them offer much promise for the near future.

Meanwhile, emissions from internal combustion engines are being reduced by improved designs and pollution control devices. Indeed, continuing monitoring tests indicate that the total amount of pollution produced by automobiles peaked out in 1967 and has been declining since then. Federal standards for 1975-1976 model automobiles require a 90% reduction in air pollutant emissions from the 1970-1971 levels. Experimental models tested in 1971 show promise of meeting these low emission levels. Thus, total emissions from automobiles should continue to decline during the next few years as older cars are replaced by newer models.

Automobile emissions are almost four times greater under stop and go traffic operations than at constant speeds of 45 to 50 miles per hour. Thus cities can reduce automobile pollution by improving traffic operations on city streets. Also, most new cars bought today have much more power than needed for normal urban driving. Indeed, some of today's automobiles have better performance characteristics than the best fighter planes of World War II. If the individual citizen really wants to do something about air pollution, he can stop buying such over-powered cars.

EXISTING TRANSPORTATION IN THE TEXAS COASTAL ZONE

THE TRANSPORTATION INDUSTRY

Three of the top four economic sectors in Texas (petroleum refining, petroleum production, and agriculture) are entirely dependent upon transportation for their value. Obviously then a healthy transportation industry is essential to a healthy economy. The transportation industry in the Coastal Zone is a vital part of its, and the State's, total economic activity. More than three-fourths of all the goods shipped from Texas are shipped from the Coastal Zone. In fact, the number of tons of goods per person handled by the Coastal Zone's transportation industry totaled more than 4 times the national average.

WATER TRANSPORTATION

Few Texans realize the importance of water transportation to the State. Over 120 million tons of goods are shipped by water from Texas ports each year. This represents almost 90% of all shipments from the Coastal Zone and almost 75% of all goods shipped from the State as a whole. Indeed, Texas rivals New York as the premier seafaring state in the nation since Texas ports handled a total of 185 million tons of goods in 1968 compared to 192 million tons in New York. Yet, Texas has a state agency specifically concerned with every other mode except water transportation.

Ocean-going ships carry about 120 million tons of goods to or from Texas each year; however, total ocean traffic has not increased in the last ten years. The reasons for this lack of growth are probably many and varied, but problems such as imbalance of traffic, congestion in ship channels, and limited channel depths must be contributing factors.

More than 85% of the ocean traffic is outbound; consequently, nearly all of the ships carrying Texas goods out must return empty. Hence, the rates charged for transportation must cover the cost of the entire voyage rather than just half of it. Traffic congestion in some of the ship channels is so severe on occasions that collisions occur. Indeed, the Houston Ship Channel is one of 14 in the nation being considered by the Coast Guard for a traffic control system - after enabling legislation is passed.

Almost half of the nation's petrochemical industry and about one-fourth of its refining capacity is concentrated in the Texas Coastal Zone. Hence, the bulk of the tonnage in ocean traffic is carried by petroleum tankers, and the size of tankers has been increasing at astounding rates in recent years. The average size tanker under construction increased from 41,000 deadweight tons in 1960 to 116,000 tons in 1970. Two tankers exceeding 400,000 tons are now under construction and a 500,000 tonner is on order. Yet, Texas ports, with a maximum 40 ft. channel depth, can only handle ships up to 45,000 or 50,000 deadweight tons. Obviously, some dramatic actions are needed if Texas ports are to be able to serve future ships.

Inland waterway traffic is also a major portion of the water transportation activities in the Coastal Zone. Barges loaded with almost 70 million tons of goods traveled the Gulf Intracoastal Waterway in Texas during 1970. About half of this traffic (36 million tons) crossed the Texas-Louisiana border and had to pass through the heavily congested locks in Louisiana. As peculiar as it may seem, conditions in the Louisiana portion of the canal have a strong impact on Texas waterway traffic.

The Texas portion of the Gulf Intracoastal Waterway is all at sea-level so that no locks are required. However, in order to reach the Mississippi River system, Texas goods must pass through several locks in Louisiana. These locks are severely restricting the flow of traffic - sometimes causing delays of 24 to 30 hours to barges waiting to pass through them. Total delay times at locks can more than double the normal travel time between Texas and the Mississippi River.

The volume of inland waterway traffic in Texas increased rapidly from 1950 until 1967, but then it leveled off. Recent industrial expansion in the Coastal Zone has been closely related to the waterway. In fact, more than 4 out of every 5 additional tons of waterborne traffic developed in the past 15 years have been on the canal. Thus, the traffic problems on the Louisiana segment of the waterway can stymy future industrial growth in the Texas Coastal Zone.

PIPELINES

The concentration of pipelines in the Texas Coastal Zone is greater than in any similar size area in the world. Crude petroleum, products, and natural gas pipelines ranging from 6" diameter to 36" diameter criss-cross the entire area. The total capacity of liquid pipelines entering or leaving the Coastal Zone is sufficient to transport more than 150 million tons each year. Sizeable increases in pipeline capacity will probably be needed if off-shore areas of Texas are developed; however, additional right-of-ways will be difficult to obtain.

RAIL TRANSPORTATION

An extensive network of railroads, including almost 3,000 miles of main-line tracks, serves the Coastal Zone and connects it to the rest of the State and the nation. A total of 55 million tons of rail freight is estimated to originate in, terminate in, or pass through the Coastal Zone each year. However, none of the major rail corridors appear to be operating at more than 20% of their basic capacity, and this basic capacity can be greatly increased through signilization and centralized traffic control if future needs require. Hence, available capacity is not a problem for railroads in the Coastal Zone, but the imbalance of traffic is a chronic problem. If the flow of ocean traffic is balanced in the future, it will probably help to balance rail traffic since the railroads play a major role in supporting the ports.

AIR TRANSPORTATION

Eight airports in the Coastal Zone are presently served by scheduled air passenger service. Almost 3 million passengers boarded planes at these airports in 1970, and if recent trends continue, this total could increase to 30 million by 1990. Such an increase in traffic will require numerous improvements to existing airports; however, additional airports probably will not be necessary. Ground access time to airports has become a significant portion of the total travel time for modern airline trips. Very few areas of the Coastal Zone are now more than 1 1/2 hours driving time from an air-carrier airport; however, this situation will probably worsen as urban areas increase in the future. Air cargo is the fastest growing form of goods movement, and the projected increase in air cargo traffic is sufficient to require substantial improvements to goods handling facilities at Coastal Zone airports.

HIGHWAY TRANSPORTATION

Highways form the backbone of the transportation system serving the land area within the Coastal Zone. Most of the 12,000 miles of highways crisscrossing the Coastal Zone are presently operating at less than half of their capacity in rural areas; however, traffic volumes increase sharply as these highways approach urban areas. Extensive highway improvements will be required to adequately serve the projected growth in motor vehicle traffic during the next 30 years.

URBAN TRANSPORTATION

All Coastal Zone cities presently have an automobile-based urban transportation system. Major arterial streets and freeways usually constitute less than 20% of the total street mileage, but they handle more than 80% of the total urban travel. The demand for urban travel has increased about 50% during the last ten years - much faster than population growth. Hence, major improvements in urban transportation facilities will probably be needed even if the population does not increase during the next 30 years. However, if the urban population doubles as expected, Coastal Zone cities will need to provide an additional 3,000 miles of major arterials and freeways as well as 15,000 miles of local and collector streets. Even so, the larger urban areas will probably need some form of mass transportation to supplement their automobile-based system.

COMPARISON OF THE NORTHEAST CORRIDOR AND THE TEXAS COASTAL ZONE

GENERAL CHARACTERISTICS

Some striking similarities exist between the Coastal Zone of Texas and the Northeast Corridor which stretches from Washington, D.C. to Boston, Massachusetts. The land areas are about the same; distances between major cities are similar; both regions have numerous seaports; and both areas are served by major elements of every mode of transportation. Of course, the Northeast Corridor is more heavily populated, but the two regions exhibit similar growth patterns if the Coastal Zone is assumed to be lagging the Northeast Corridor by 150 years.

The population of the Texas Coastal Zone will probably never reach 42 million, but it will increase enough to create the potential for many of the same transportation problems that are now evident in the Northeast Corridor. A closer look at some of these problems can yield information which can be used to avoid them in the Texas Coastal Zone.

URBAN AREAS

The population of the Houston area is now only 1.7 million, but it is expected to exceed 3 million in the next 30 years. Thus, a comparison between Houston and Washington, D.C. (2.5 million) as well as Boston (2.7 million) should provide useful information for future plans in Houston. Houston presently covers more land area than either Washington or Boston even though its population is less. This is indicative of the lower overall population density in Houston which is largely determined by the type of housing. More than 70% of the residents in Houston live in single-family houses compared to 50% of those in Washington, D.C. and 40% of the Boston residents.

The automobile is the backbone of the urban transportation system in all three cities; however, the northeastern cities have a much higher dependence upon transit modes. Washington, D.C. is served by three bus companies using a total of almost 1,800 buses. Boston, on the other hand, has a rail rapid transit system, street car and trolley lines, and commuter rail lines in addition a fleet of about 1,200 city buses. Houston's transit company operates a fleet of less than 350 buses. Even with all of its rail facilities, Boston has more miles of freeways (190 miles) than either Washington or Houston (160 miles each).

Washington, D.C. seems to be the only one of these three cities with a thriving transit operation. It has the highest level of transit ridership of any city its size in the nation, and all three privately

privately owned bus companies are in sound financial condition. The Massachusetts Bay Transportation Authority, Boston's publicly owned transit company, on the other hand, has experienced severe problems with decreasing ridership and rapidly increasing operating deficits. Its estimated operating deficit for 1971 was $75 million - more than 30 dollars per person in the Boston area.

Boston and Washington, D.C. serve about the same total number of transit riders; however, Boston is splitting their ridership between several modes while Washington uses only buses. This factor may explain some of the financial problems of Boston's transit system. Washington, D.C. is currently building a 98-mile rail rapid transit system at an estimated cost of more than $3 billion. It will be interesting to see if this new system attracts new riders or just diverts passengers from existing bus operations.

Houston's privately owned bus company has managed to maintain a financially sound operation despite a decreasing ridership trend. However, if recent trends in automobile ownership and low density developments continue, the transit company's condition will probably change for the worse. Factors identified in this comparison of cities should be considered in future transit plans for Houston.

REGIONAL DEVELOPMENT

The Texas Coastal Zone and the Northeast Corridor are both served by major elements of every mode of intercity transportation, and their economic activities are heavily dependent upon these transportation services. Water transportation is extremely important to both regions. There are 23 major ports in the Northeast Corridor and 13 major ports in Texas. Yet, Texas ports shipped out more tons of goods than did the northeastern ports. This fact points out one of the basic differences in the two areas - the Coastal Zone exports goods while the Northeast Corridor imports them. Thus, a continuous flow of goods into the Northeast Corridor is essential to the survival of its residents - a long breakdown in transportation would be catastrophic.

Between 1950 and the mid-1960's, substantial improvements were made in intercity travel conditions in both regions because of advancements in technology. However, these trends toward lower travel times have already reversed in the Northeast Corridor and they appear to be bottoming out in the Coastal Zone. The Northeast Corridor cannot build new highways fast enough to keep up with the demand and air traffic is highly congested so they are experimenting with high speed rail service as a partial solution. Eventually, the Coastal Zone may also need high speed rail service.

Perhaps the most important lesson to learn from their experience is the need to recognize the permanency of major transportation corridors and to take actions that will insure future flexibility within these corridors. The Northeast Corridor stretches across 119 counties in 10 states while the Coastal Zone lies entirely in one state. Thus, Texas is in a far better position to plan for future problems than was the Northeast Corridor.

FUTURE ALTERNATIVES

SUPER-DRAFT PORT

Maximum ship sizes, especially tankers and bulk carriers, have been increasing at an astounding rate during the last 30 years. If these trends continue until 1985, the maximum size tanker will exceed 1,000,000 deadweight tons, and the maximum size bulk carrier will be at least 300,000 tons. These rapid increases in ship sizes are a result of economic considerations in ocean transport. The productivity of a crew can be doubled by either doubling the size of a ship which requires a 42% increase in horsepower or by doubling the ship's speed which requires a 550% increase in horsepower. Thus the trend has been toward larger ship sizes.

The maximum depth of Texas ports today is only 40 feet; therefore, ships exceeding 50,000 deadweight tons cannot enter these ports. Depths of 75 feet will be required to serve ships up to 250,000 tons in size, and depths of about 115 feet will be required for the one million ton ships. If minimum economical sizes of tankers and bulk carriers are to be served in the future, much deeper port facilities will be required.

Texas can pursue several alternative courses of actions relative to future needs of the ocean-going segment of the total transportation system. These alternatives include the following:

(1) No increase in depth;

(2) Deeper channels;

(3) Off-shore terminals; and

(4) Super-port.

Each of these alternatives have some obvious advantages and disadvantages; however, their consequences should be evaluated further before Texas chooses a course of action.

INLAND WATERWAY SYSTEM

The section of the Gulf Intracoastal Canal in Louisiana is an essential element of the Texas waterway system; however, traffic congestion and delays at locks in this segment are deterring the growth of waterway traffic in Texas. A total of 65 million tons of cargo traveled the Louisiana segment of the canal in 1970. Some of this traffic was local in nature, but 36 million tons of it was traveling to or from Texas. Operating under ideal conditions 24 hours a day, 365 days a year, the Vermilion lock can only pass 70 million tons of goods per year. Thus, Texas traffic alone consumes at least half of the ultimate capacity of this lock.

Transportation services such as those provided by the waterway are essential to the economic livelihood of the Coastal Zone. The alternative approaches that might be considered with regard to the waterway include the following:

(1) No waterway improvement;

(2) Improved locks; and

(3) New constant-level waterway.

Here again, obvious advantages and disadvantages of each can be identified, but further study is needed before Texas selects a course of action.

COASTAL HIGHWAYS

The demand for more recreational facilities along the Texas coast and improved highway access to them is expected to increase in the future. Also, increased intercity travel demands will probably necessitate construction of a freeway facility parallel to the Coast. However, new highways in the vicinity of the coastline can significantly influence the type and extent of land development along the beach areas. The nature of future development will differ depending upon the location and design of any new highway facilities.

Alternative approaches that might be considered include the following:

(1) No new highways;

(2) Beach highway;

(3) Coastal highway;

(4) Inland freeway; and

(5) Two facilities.

Each of these alternatives will have different effects upon the nature of future development. These factors should be considered before decisions concerning highway facilities are made.

URBAN GROWTH

The urban population of the Coastal Zone has more than doubled in the last 30 years, and it may double again in the next 30 years. Future transportation problems will largely depend upon how well the cities and the State manage to locate and shape new urban developments and transportation systems.

Two or three new urban centers might possibly be developed along the Coastal Zone in order to disperse the population and minimize the amount of redevelopment required in existing cities. However, such a course of action would require aggressive steps on the part of the State to provide transportation facilities and entice industry to locate at the new sites.

Without stringent external controls, new urban development will tend to occur around existing cities. If this development is carefully planned and properly managed , the net result can be an improvement in existing urban forms. Houston will face some unique problems in that it must try to develop an urban form that can be more effectively served by mass transportation. The Beaumont-Port Arthur-Orange area can easily transition into a unified urban area with three focal points. Other cities in the Coastal Zone have a great deal of flexibility providing that new developments are compatible with existing autombile-based transportation systems.

URBAN TRANSPORTATION

The principal decision concerning future urban development should be the nature and character of urban environment desired. Once this is determined, the transportation system must be designed to be compatible with the desired type of development. All of the cities in the Coastal Zone consist primarily of single-family dwelling units so their transportation systems should continue to be based primarily upon the automobile. However, this places some corresponding constraints upon the city size and extent of development at major focal points.

With a properly designed system of arterial streets, a city can grow to a population of about 300,000 persons before an urban freeway system is needed. Once a city is large enough to need a freeway system, the constraints associated with transportation systems serving a single focal point should be considered. Automobiles operating on an ideal arterial street and freeway system can serve a total population of about 2 million persons surrounding a single focal point. Larger urban areas must either develop multiple focal points or face the necessity of supplementing their automobile based commuter system with some form of mass transportation and providing a people-mover system to aid circulation within the focal point.

Urban streets serve a variety of functions which are important to the overall operation of the city; however, the major functions of movement and access are competitive in nature so a single facility cannot be designed to provide a maximum of each. A classification of streets according to the relative importance of these two functions can be extremely useful in developing plans for urban street systems. The following four classifications, listed in order of decreasing importance of the movement function, are suggested:

(1) Primary arterials;

(2) Secondary arterials;

(3) Collectors; and

(4) Local streets.

Access controls are needed along arterial streets in order to protect their primary function of movement. Frequent driveways and street intersections result in numerous turning movements that greatly hinder the flow of traffic. Public oppostion to such controls often subsides once the land owners recognize the difference in access and accessibility. Commercial firms seek locations along primary arterials because of the high level of accessibility that they provide over a broad market area. Access to the commercial sites can usually be provided from streets with lower levels of classifications so that the good accessibility of the arterial is not destroyed in the process of development.

Recent trends toward larger scale residential developments (50 acres or more) have increased the opportunity for implementing the functional classification concept in street design. Modern limited access subdivisions result in better traffic operations on the arterial streets, and they provide a more relaxed atmosphere in the residential area. Future urban developments in the Coastal Zone will provide a better living environment if the suggested guidelines concerning street system plans are followed.

OTHER TRANSPORTATION CONSIDERATIONS

Major transportation corridors are a permanent commitment to the movement of persons and goods between areas of concentrated activities. The types of facilities within the corridors might change drastically over the years, but the need for transportation remains as long as the activity centers exist. The first major transportation facility installed to connect two activity areas is usually located on the most desirable alignment. Thus, subsequent changes in capacity or level of service can best be accomplished along the same route if adequate flexibility is available. Future transportation needs in the Coastal Zone can be met more effectively if the cities, counties, and the State embrace and apply the concept of permanent transportation corridors.

A major transportation corridor might serve several different modes, and the facilities might change with time. However, if sufficient right-of-way is acquired and protected, the corridor will have flexibility to meet changing needs in the future. A major intercity transportation corridor today might contain a six-lane freeway, two freight rail lines, a high-speed rail facility, and several pipelines. Thus, right-of-way widths of 1/4 mile or more would be appropriate. Major urban corridors might contain a ten-lane freeway, a fixed-way transit line, and some goods movement facilities. Right-of-way widths of 1,000 feet might be considered for such urban corridors.

A transportation terminal is not necessarily the end of a line but merely a location where two or more modes of transportation can interchange traffic. Terminal facilities are normally oriented primarily toward serving one mode, as the name airport or seaport implies, but the basic function of the terminal is to provide for modal interchanges.

Hence, future plans for transportation terminals in the Coastal Zone should give due consideration to all modal interchanges that might need to occur there.

CONCLUSIONS AND RECOMMENDATIONS

This study constitutes an overall evaluation of the total transportation system serving the Coastal Zone of Texas. One purpose of the study is to identify actions that the State might take to avoid future problems and to instigate solutions to existing problems. Significant conclusions and corresponding recommendations are summarized below for various topic areas.

WATER TRANSPORTATION

Conclusions

1. Water transportation is important to the entire State.

2. Texas ports need deeper facilities.

3. Traffic conditions on the Louisiana segment of the Gulf Intracoastal Waterway concern Texas.

Recommendations

1. Texas should create or designate a State agency to be specifically concerned with water transportation problems.

2. Texas should conduct further studies of super-draft ports.

3. Texas should evaluate further the problems on the inland waterway and formulate a plan of action.

TRANSPORTATION/LAND-USE RELATIONSHIPS

Conclusions

1. Recognition of the relationships between land/use and transportation is essential for effective planning.

2. Transportation facilities can be used to influence land developments.

3. Mass transportation will be needed in some Coastal Zone Cities.

Recommendations

1. Texas should encourage its cities to identify their preferred urban form.

2. Transportation/land-use relationships should be considered in the design and location of all new transportation facilities.

3. The State should monitor plans for new mass transportation systems in cities.

PLANNING AND IMPLEMENTATION PROCEDURES

Conclusions

1. Land-use management is needed.

2. Existing planning and implementation procedures are inadequate.

Recommendation

1. The State should conduct a study of procedures needed for effective transportation planning and implementation.

TRANSPORTATION CORRIDORS

Conclusions

1. The need for transportation along major corridors will continue as long as the urban areas exist.

2. Lessons from the Northeast Corridor can be valuable to Texas.

Recommendations

1. Texas should adopt the concept of permanent transportation corridors.

2. The State should define major transportation corridors in the Coastal Zone.

ENVIRONMENTAL CONSIDERATIONS

Conclusions

1. Environmental effects of transportation are especially critical in the Coastal Zone.

2. Sufficient data are not available on environmental effects of transportation.

Recommendations

1. Environmental effects should be considered in the transportation planning process.

2. Texas should conduct further studies of the environmental effects of Coastal Zone transportation systems.

RECREATIONAL TRAVEL

Conclusions

1. An increase in recreational activities is expected in the Coastal Zone.

2. Indiscriminate developments along the coastline can permanently destroy some of the natural attractions of the area.

Recommendation

1. Texas should establish specific goals and objectives for future development in the Coastal Zone, and all future transportation facilities should be planned so that they help accomplish these goals and objectives.

GENERAL TRANSPORTATION CONSIDERATIONS

URBAN TRANSPORTATION

BALANCED TRANSPORTATION SYSTEMS

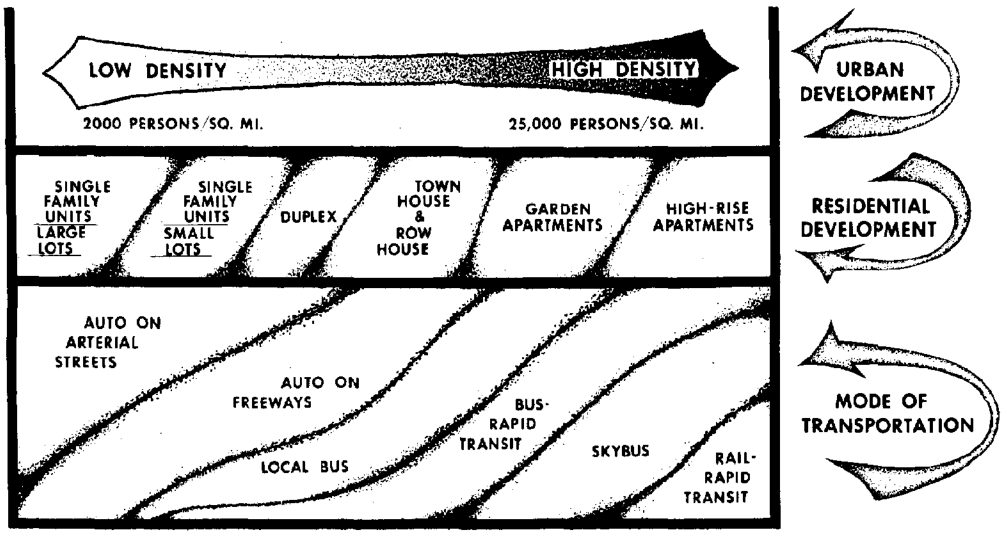
The term "balanced transportation" has been used by many to mean a "mixture of transportation modes", but it should be used to denote a balance between land use intensity and transportation - whatever the mode or modes. The most critical key to proper planning of an urban transportation system is a recognition of the interrelationship between land use and compatible forms of transportation. Many cities have evolved a practice of developing a land use plan and a transportation plan separately. Herein lies a great fallacy of judgement for these two plans are, and must be, one in the same. A decision with respect to one carries with it a corresponding limitation in the rational decisions that may be made with respect to the other.

A low density urban development, consisting primarily of single family dwelling units, cannot be served by a rail rapid transit system. Conversely, a high density urban development, including many high-rise apartment buildings, cannot be served by a transportation system based upon the automobile.

The interrelationship between various types of residential developments and compatible modes of transportation is schematically portrayed in Figure III-1. The upper portion of the figure depicts the overall measure of the type of urban development, expressed in population density. The center segment depicts the type of residential development that would be predominate in a city of such density. The lower segment reflects the mode of transportation, or mixture of modes, that would be appropriate to serve a city of that type. Of course, the interrelationships depicted by this figure are oversimplified, but a recognition of this concept is essential if future urban developments within the Coastal Zone are to function properly.

Since most of the people live in single family dwelling units, cities within the Coastal Zone have developed at relatively low average densities that can best be served by the automobile operating on a well designed system of freeways and arterial streets. Generally, these urban transportation systems function quite well, but peak-period problems are caused by severe fluctuations in land use intensity within the city. Residential densities range from less than 1000 persons/sq mile in "country club" type subdivisions to more than 10,000 persons/sq mile in some garden apartment complexes. Business and commercial areas result in daytime population densities ranging from 20,000 persons/sq mile

FIGURE III-1 BALANCED TRANSPORTATION SYSTEMS



Source: Reference 9

A balanced transportation system can only be achieved through a recognition of the mutual dependence of urban land use and mode of transportation. Single family houses cannot be served economically by rail rapid transit nor can high-rise apartments be served adequately by an automobile-based transportation system. A city can choose either the type of development or the type of transportation system desired but that decision carries with it corresponding limitations concerning the other.

in some suburban shopping centers to more than 100,000 persons/sq mile in some downtown areas.

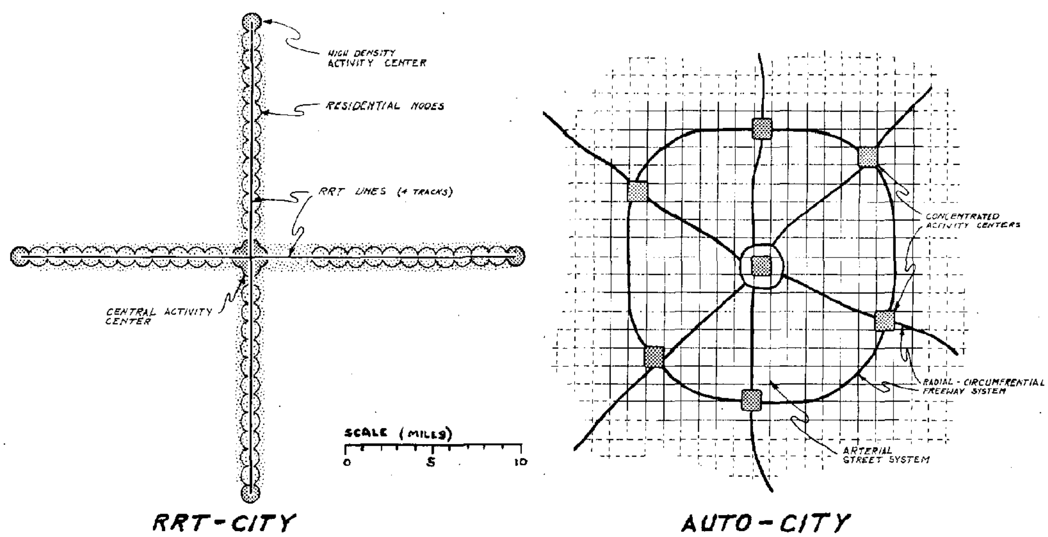
Although recent growth is still at relatively low densities, the need for some form of mass transit to supplement the automobile is increasing in some cities in the Coastal Zone. Indeed, the level of downtown development in Houston has already surpassed that which can be adequately served by automobiles alone. Further, the percentage of urban population living in multifamily structures almost doubled (from 15% to 29%) between 1960 and 1970. However, due to the relatively low average densities, careful planning and sound judgement will be required in developing supplemental mass transportation systems to serve these cities.

EXAMPLES OF URBAN FORM/TRANSPORTATION RELATIONSHIPS

The integral relationships between land use and compatible transportation modes might be best demonstrated by selecting two drastically different modes of transportation and evaluating the urban forms that each would require. Automobiles on the one hand and Rail-Rapid-Transit on the other constitute both ends of today's urban transportation spectrum. Cities could be designed to be served adequately by either mode of transportation, but they would require totally different urban forms and would result in significantly different lifestyles.

The resulting urban forms for two such cities would probably be similar to those shown in Figure III-2. The Auto-City would be quite similar to the type of urban development of existing cities in the Coastal Zone since these cities have been greatly influenced by the automobile. Because there are no existing cities that are similar to the RRT-City concept shown here, it is described in greater detail in the comparisons that follow.

FIGURE III-2 COMPARISON OF URBAN FORMS FOR ONE MILLION PERSONS



Automobiles on the one hand and Rail-Rapid-Transit on the other constitute both ends of today's urban transportation spectrum. Cities could be designed to be served adequately by either mode of transportation, but they would require totally different urban forms. The Auto-City, would be quite similar to the type of urban development currently existing in the Coastal Zone. There are no existing cities that are similar to the RRT-City concept. People would live in high-rise apartment buildings and walk to the grocery stores, transit stations, schools, and recreational facilities. RRT trains would connect their neighborhood to all other nodes in the city.

The basic neighborhood unit in the Auto-City would be a large sub-division covering about one square mile, bounded by arterial streets, and containing about 1000 single family houses with individual yards. The arterial street pattern would form a gridiron with one mile-spacing. A radial-circumferential system of freeways would be superimposed over the street pattern to complete the major transportation thouroughfare system. This would stimulate a strong focal point in the center (downtown) but other areas of concentrated activities would develop at accessible locations. All in all, the Auto-City might look very much like Houston today.

In the RRT-City, on the other hand, people would live in residential nodes containing about 25,000 people centered around a transit station. Each node would include about one hundred high-rise apartment buildings (10 stories tall, housing 80 families each), four elementary schools, one junior high school, three or four supermarkets, and maybe one office building. Buildings would be clustered around the transit station in a circular pattern so that very few walking trips would have to be more than 1/2 mile long. Recreational activities and open spaces (parks, stables, bridle paths, golf courses, ball parks, tennis courts, etc.) would surround each residential node.

The RRT corridors might form a cross so that the focal point (downtown) would be at their intersection. Each corridor would contain 4 sets of tracks to provide for peak-hour demand. Each of the 4 legs extending outward from the center would include 10 residential nodes with the stations spaced about 1 mile apart. Thus each leg would contain housing for 250,000 persons - enough to support 5 high schools, 1 junior college, 2 large hospitals, a large regional shopping center, and considerable industrial activity. In addition to the highly developed Central Business District located at the focal point, the entire city would have need for an intercity transportation terminal (airport, bus station, train station, etc.), one large university, a cultural center, and other similar activities. As many of these types of concentrated activities as practical should be located on the outer ends of the corridors in order to achieve some degree of balance in peak-hour traffic.

If two such cities were properly designed, they would both have pleasant urban environments, but the living conditions would be drastically different. In the Auto-City people would live in single family houses with individual yards. Residents of the RRT-City would live in high-rise apartment buildings and there would be no individually owned lawns or gardens. Each apartment building, however, could probably have its own swimming pool and well landscaped lawn. Thus each city would have some distinct advantages and disadvantages relative to the other.

One of the significant differences in the two cities is the type of mobility provided by the transportation systems. In the Auto-City each family would have an automobile available to make any trip they desire, urban or intercity, at any time. There would be no provision for automobiles in the RRT-City; therefore, the longer urban trips and all intercity trips would have to be made on public transportation modes. A great many of the shorter urban trips would have to be made by walking, but usually no further than 1/2 mile. Thus the person who could not walk such distances would be severely disadvantaged in the RRT-City just as the non-driver is disadvantaged in the Auto-City.

The total investment in transportation would be somewhat less in the RRT-City, but housing costs would be significantly higher. High-rise apartment buildings are constructed of concrete and steel and each dwelling unit must be fireproofed. Thus the unit cost for an apartment in a high-rise building would be about double that for a single family house with the same floor plan. A comparison of significant characteristics of these two cities, presented in Table III-1, shows that the total initial investment in housing and transportation is slightly higher in the RRT-City. However, the transit vehicles should last for twenty years, as compared to ten years for automobiles; consequently, the total annual per capita costs for transportation and housing would be about the same in either city.

TABLE III-1 COMPARISON OF AUTO-CITY AND RRT-CITY FOR ONE MILLION PERSONS

Characteristic	Auto-City	RRT-City
General		
Types of Residential Structures	Single Family Houses	10 Story Apt. Blgds.
Land Area Required, sq. miles	330	46
Gross Population Density, ppsm	3,000	22,000
Maximum Population per Focal Point, millions	2	6
Minimum Population per Focal Point, millions	None	0.5
Travel Time to CBD during Peak-Hour, minutes	30	25
Travel Time to CBD during Off-Peak, minutes	20	25
Time Required for Longest Urban Trip, minutes	35	60
Transportation Investment, Millions of Dollars		
Vehicles	3,500	2,920
Facilities	2,960	1,650
Elevators in Residential Bldgs.	--	600
Total Transportation	6,460	5,170
Housing Investment, Millions of Dollars	7,800	17,400
Total Investment in Housing & Transportation, Millions	14,260	22,570
Annual Costs per Capita, Dollars		
Transportation (Vehicles, Facilities, Operations, etc)	1,045	495
Housing	625	1,370
Total Housing and Transportation	1,670	1,865

If two such cities were properly designed they would both have pleasant urban environments, but the living conditions would be drastically different. In the Auto-City people would live in single-family houses while in the RRT-City they would live in high-rise apartment buildings. Each would have some distinct advantages and disadvantages. The total annual costs for transportation and housing would be about the same in either city.

The comparison made so far has been for cities with a population of one million persons, as their populations increase the differences between the Auto-City and the RRT-City become even more significant. Both modes have limitations in the number of persons who can be transported into the central business district during peak-periods. An Auto-City could only support a population of about 2 million persons per focal point. RRT-Cities, on the other hand, could probably serve a population of 6 million persons from a single focal point.

A comparison of possible urban forms for Auto- and RRT-Cities of four million population is shown in Figure III-3. The Auto-City would require at least two major focal points and might resemble the overall form of the Dallas-Ft. Worth Metropolitan Area. The RRT-City could still have a single focal point, but an extensive people-mover system would be needed to supplement the pedestrian mode in the downtown area.

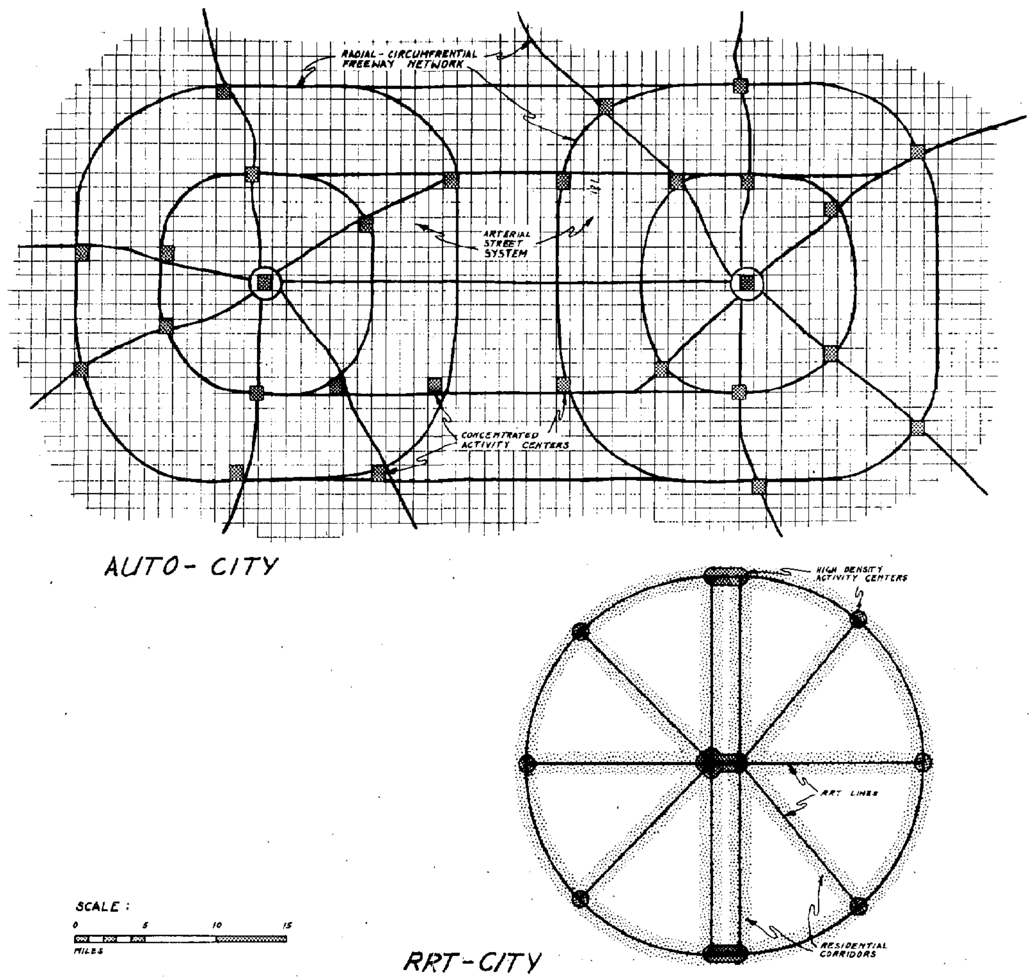
Automobile and rail-rapid-transit represent the extreme ends of today's urban transportation spectrum. The types of urban development required for total dependence on either of these modes are so different that it is not surprising that no city has yet been able to successfully integrate both modes into their urban transportation system. Indeed, one of the greatest challenges facing various cities of the Coastal Zone in the future is to find ways to shape their urban forms so that they can achieve an effective balanced transportation system.

URBAN FORM CONCEPTS

If properly done, either of the example urban forms presented would have a balanced transportation system. In other words, the urban form and the transportation system would be entirely compatible. However, these two concepts were developed to conform to the ends of the spectrum of urban transportation modes available today. Most large cities of the future will probably require a blend or mixture of transportation modes because of variations in land use intensities within the urban area.

Population density is the most commonly used measure of the intensity of urban development. It is usually expressed in units of persons per square mile (ppsm). However, the values of population density quoted in various reports are sometimes confusing because they may be calculated on different bases. The density of a specific development may be calculated by dividing the number of persons contained within that development by its land area. For the most part though, population density figures denote the average intensity of the total urban area which includes land devoted to open spaces, commercial, industrial, and residential uses as well as transportation facilities.

FIGURE III-3 COMPARISON OF URBAN FORMS FOR FOUR MILLION PERSONS



As their populations increase the differences between the Auto-City and the RRT-City become more significant. Due to limits in downtown concentrations that can be served by automobiles, an Auto-City of 4 million persons will require at least two major focal points. The overall urban form of such an Auto-City might resemble that of the Dallas-Ft. Worth Metropolitan area. A RRT-City, on the other hand, could still have a single focal point but a people-mover system would be needed to supplement the pedestrian mode in the downtown area. The types of urban development required for total dependence on either mode are so different that it is not surprising that no city has yet been able to successfully integrate both modes into their urban transportation system.

Densities associated with various developments also vary depending on the time of day. Generally population densities are classified as either nighttime densities or daytime densities. Residential developments will have a high nighttime density whereas developments such as shopping centers, offices, etc., will have high daytime densities. It is this time of greatest density which is of concern in the transportation planning process.

Examples of the net population density and corresponding population density of the entire urban area are presented for various type residential developments in Table III-2. Also, examples of net daytime population densities for various types of commercial developments are presented in Table III-3. These examples should lend some meaning to the types of physical developments required to achieve certain urban population densities.

Existing urban development in the Coastal Zone is largely oriented toward an automobile-based transportation system. More than 80% of the urban growth has occurred since the automobile became a major influencing factor - about 1920. It was the advent of the automobile that enabled such cities to grow so large and still be composed primarily of single-family houses. The resulting overall population densities are less than 3000 persons per square mile which, according to Figure III-1 (page III-2), should be entirely compatible with an automobile-based transportation system. However, peak-period transportation problems are often produced by severe variations in land use intensity within the city.

Total urban population in the Coastal Zone is expected to double in the next 30 years. Existing developments will not be abandoned, however, so this growth must be accommodated in a manner that is compatible with existing automobile-based transportation systems. In some cases additional modes of transportation will be needed to supplement the automobile. Future developments can be planned and controlled so that existing urban forms are modified accordingly. Three conceptual urban forms that might be effectively served by supplemental modes of transportation are shown in Figure III-4.

Almost 30% of the urban population in the Coastal Zone presently lives in multifamily housing units - most of which are garden apartments. If such a large proportion of future residents are willing to live in multifamily structures then urban forms resembling the High Density Corridors Concept can be developed in some cities. These corridors would be served by a fixed-way mode of transportation; however, this concept would be workable only if most of the high-density residents also want to travel along the corridor.

The Transportation Terminal Concept can be implemented with less change in residential patterns than required for the high-density corridor concept. Parking facilities can be constructed at dispersed

TABLE III-2 EXAMPLES OF POPULATION DENSITIES ASSOCIATED WITH VARIOUS RESIDENTIAL DEVELOPMENTS (NIGHTTIME DENSITIES)

Type Of Residential Development	Description Of Development	Assumed Ave. Sq. Ft. Of Lot Per Dwelling Unit	Dwelling Units Per Acre	Net Population Density Within The Residential Development (ppsm)	Corresponding Population Density Of The Urban Area (ppsm)
Single Family	Large house in well-to-do neighborhood	32,000	1	2,200	880
Single Family	Relatively large house in middle class neighborhood	16,000	2	4,400	1,750
Single Family	Average new sub-division development	9,000	3.67	8,000	3,200
Townhouse	Relatively large individual units	3,000	10	16,000	6,400
Townhouse	Relatively small individual units	2,000	14	22,400	9,000
Garden Apartment	Typical 2-Story development	-	15	19,000	7,600
Garden Apartment	Typical 3-Story development	-	25	32,000	13,000
Multi-Story Apartment	12 Story high rise apartment development	-	85	92,500	37,000

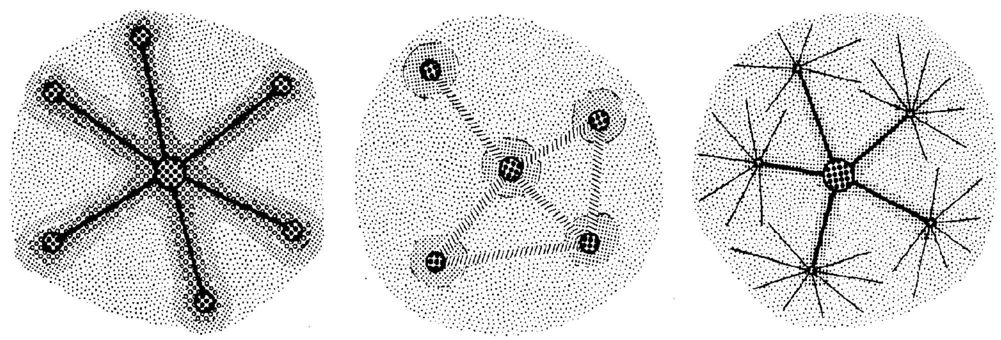
TABLE III-3 EXAMPLES OF NET POPULATION DENSITIES ASSOCIATED WITH COMMERCIAL DEVELOPMENTS (DAYTIME DENSITIES)

Type Of Development	Description Of Development	Approx. Land Area Of Development (Acres)	Approx. No. Of Persons Within The Development At One Time On An Average Day	Equivalent Density Per Square Mile (ppsm)
Community Shopping Center	Approx. 150,000 sq.ft. Gross Leasable Area Average Size Development	30	850	18,000
Regional Shopping Center	Approx. 1,000,000 ft. Gross Leasable Area Large Regional Center	80	5,700	46,000
Central Business District	Comparable to intensity of Development in Houston, Texas	900	135,000	100,000

Source of Data: Reference 10

Population density is the most commonly used measure of intensity of urban development. Density values are sometimes calculated based upon the land area and population contained within a specific development. For the most part though, the population density values denote the average intensity of the total urban area. Most Coastal Zone cities have average population densities of less than 3000 persons per square mile. However, peak-period transportation problems result from severe fluctuations of population densities within the city if the transportation system is not modified to serve the areas of high density.

FIGURE III-4 URBAN FORM CONCEPTS FOR MIXED TRANSPORTATION SYSTEMS



Urban population in the Coastal Zone is expected to double in the next 30 years. The automobile will still be the backbone of the urban transportation system, but it will need to be supplemented by other modes of transportation in the larger cities. Careful planning and effective land development control is essential if the net result is to be an effective balance between the urban form and the transportation system.

locations and connected to major focal points by high speed transit facilities. Thus, the major areas of congestion can be relieved and the low density residential areas can be effectively connected to high density focal points. The transportation terminal concept, as shown, does not offer the resident a good alternative to owning a car. However, after the fixed-way transit modes are installed high-density residential development might occur along some of the routes. The resulting urban form would be a blend of the High Density Corridors and the Transportation Terminals concept.

An urban form resembling the Multiple Focal Point Concept can be created by limiting the development in any one focal point to that which can be served by the automobile. These focal points could then be connected by high speed, non-stop transit modes so that they could function almost as a single concentrated area.

Of course there are several other urban form concepts as well as combinations of these that could possibly be developed as the urban population of the Coastal Zone continues to increase. Nevertheless, careful planning and effective land development control is essential if the net result is to be an effective balance between the urban form and the transportation system.

URBAN TRANSPORTATION MODES

Several modes of urban transportation are presently available for utilization in the movement of people including the following:

<u>Automobile</u> - 2- to 6-passenger, privately owned vehicles operating on a system of streets and freeways;

<u>Local Bus</u> - 30- to 50-passenger buses operating on streets with the automobile;

<u>Bus Rapid Transit</u> - buses operating on reserved lanes, exclusive busways, or on freeways with metered mixed flow;

<u>Personal Rapid Transit</u> - fully automated, 6-passenger vehicles operating on exclusive guideways and providing service on a demand basis.

<u>Skybus</u> - fully automated, 35-passenger vehicles operating on an exclusive guideway singly or in trains of up to 10 vehicles; and

<u>Rail Rapid Transit</u> - 75-passenger electrically powered rail cars operating on exclusive rail lines singly or in trains of up to 10 vehicles.

Numerous other specialized forms of urban transportation have been proposed recently but they are only variations of the six basic types listed above. Monorail, for example, has the same service characteristics as rail rapid transit but it has more technological problems and actually costs more than the conventional system. Some of the more exotic concepts such as Tracked Air Cushion Vehicles (TACV) and Tubetrains are in very early stage of development and can not be seriously considered within the present planning horizon.

These six different modes of urban passenger transport are listed in order of decreasing flexibility. The automobile is the most flexible mode since it can be operated independently throughout the urban area on the street and freeway system. The local bus also operates on this extensive system but it is not as responsive to each passenger's desires. In contrast to this, the skybus and rail rapid transit are fixed-way modes that operate on their own right-of-way. Consequently they do not have to contend with congestion caused by other traffic, but their service area is permanently limited to the range of their fixed way.

Personal Rapid Transit systems offer a compromise between automobiles and conventional fixed way modes. Automated vehicles respond to individual demands but they operate only within the limits of their fixed way. The overall system design might vary in complexity from a simple horizontal elevator to a large system of computer controlled vehicles operating on an extensive network of guideways. Generally though, personal rapid transit systems are more applicable to serving internal circulation needs within a congested area rather than commuter traffic (11).

Bus Rapid Transit systems offer advantages of both the fixed-way and flexible modes. The buses have the flexibility of operating on the street system on either end of the run but have guaranteed freedom of movement by using an exclusive busway for the "line-haul" portion of the route which might otherwise be congested. The primary disadvantage of this approach is the cost of providing a fixed-way for buses only. This drastically increases the average cost per passenger mile in corridors that do not have a large passenger demand. In order to minimize this cost, some people have proposed reserving lanes on existing freeways for buses; however, there are severe operational problems associated with reserved freeway lanes (12).

The Bus-Freeway system is a variation of the Bus Rapid Transit concept in which buses operate on a freeway in mixed flow with automobiles but the traffic entering the freeway is metered to prevent congestion on the freeway. By giving priority to the entry of buses, the number of persons traveling on the freeway can be increased even though the number of vehicles is reduced. The cost of freeway surveillance and control is much less than the cost of an exclusive busway and automobiles can utilize all remaining freeway capacity. Thus the Bus-Freeway concept is highly suited for serving corridors with light to moderate transit passenger demands. (13).

Many articles have appeared in the literature in recent months advocating rail rapid transit systems as the only appropriate solution to urban transportation problems. Part of this support for RRT is based upon some misleading information that frequently appears in the literature. Capacities of 60,000 persons/hour are quoted for RRT lines and compared to observed flow rates of 2500 persons/hour on typical lanes of freeways. It is seldom mentioned that these capacities can only be achieved with the RRT cars packed so full that at least 2 out of every 3 passengers must stand - as indicated by the data shown in Table III-4. Also, the term "rapid" is somewhat misleading since these data show that none of the heavily loaded lines achieve average operating speeds as high as 30 miles per hour. People are led to believe that rail rapid transit is a new concept when actually it predates the automobile. The first systems actually were "rapid" in comparison to the horse-drawn trolleys that they replaced in the 1890's.

A realistic comparison of capacities of various urban transportation modes, based upon the number of seats available, is presented in Table III-5. This comparison shows that a Bus-Freeway system, with buses utilizing only half of the available vehicle capacity of a single

TABLE III-4 RAIL RAPID TRANSIT - OBSERVED PEAK HOUR VOLUMES

Location	Trains Per Hour	Headway (Seconds)	Actual Passenger Load	Seating Capacity Per Car	Seating Capacity Per Train	Seating Capacity Total	% Seated	Average Speed
NEW YORK	32	112	61,400	60	600	19,200	31	24.5
NEW YORK	31	116	44,510	40	360	11,160	25	19.6
NEW YORK	30	120	62,030	60	600	18,000	29	28.7
TORONTO	28	128	35,166	62	496	13,888	39	17.6
CHICAGO	25	144	10,376	49	294	7,350	71	24.5
NEW YORK	24	150	36,770	40	360	8,640	23	19.5
CLEVELAND	20	180	6,211	53	318	6,360	100	28.0

SOURCE: Reference 14

Existing Rail Rapid Transit lines can carry more than 60,000 passengers/hour, but only with two out of every three passengers standing. The term "rapid" is somewhat misleading since none of the RRT systems have been able to achieve overall average speeds of 30 mph.

TABLE III-5 CAPACITIES OF URBAN TRANSPORTATION MODES

Mode	Flow Rate, Units/Hour/Lane	Seats Per Vehicle	Capacity Seats/Hour
Automobile or Freeway	2000 autos	5 per auto	10,000
Bus-Freeway	500 buses, 1000 autos	50 per bus 5 per auto	30,000
Exclusive Busway	1250 buses	50 per bus	62,500
Skybus	40 ten-car trains	35 per car	14,000
Rail Rapid Transit	40 ten-car trains	75 per car	30,000

When total capacities of various urban transportation modes are calculated based upon the number seats per hour, an exclusive busway is shown to have the highest capacity. However, ultimate capacity is not the most important consideration in selecting new modes for Coastal Zone cities. Maximum peak-hour transit demands are not expected to exceed 20,000 passengers in any of the major travel corridors during the next 30 years.

freeway lane, has the same seat capacity as a modern RRT lane. An exclusive busway offers the highest theoretical capacity per lane of all existing modes; however, capacity is not really the primary consideration for Coastal Zone cities in selecting new modes of urban transportation.

Many of the trips being made on typical urban freeways have such diverse origins and destinations that they can not be effectively served by transit. Studies of major travel corridors in various Coastal Zone cities indicate that the current maximum peak-hour transit demand potential ranges from 5000 to 10,000 passengers. Even with the projected increase in population during the next 30 years, it is unlikely that any corridor will develop a total peak-hour transit demand of more than 20,000 passengers unless drastic changes in urban form occur. Thus it appears that costs and service characteristics of various modes are of greater concern than ultimate capacity.

Fixed-way modes are characterized by high initial costs but lower average operating costs as the volume of ridership increases. Driver wages are a major portion of the total operating costs of bus and rail transit systems. In fact, in most of the city bus operations today, labor costs constitute about 60% of the total cost of operation. Of course, driver costs are not included in the operating costs for automobiles. Approximate costs for various modes of transportation are compared in Table III-6.

TABLE III-6 COSTS OF URBAN TRANSPORTATION MODES

Mode	Operating Costs, ¢/Mile		Capital Costs Per Lane-Mile Of Traveled Way
	Per Vehicle Mile	Per Seat Mile	
Automobile	10	2.0	$900,000
Bus-Freeway*	35	1.8	$900,000
Exclusive Busway	90	1.8	$800,000
Skybus	55	1.6	$1,250,000
Rail Rapid Transit	110	1.5	$2,500,000

Source of Data: Reference 13

*Assumes a mixture of 500 buses and 1000 autos.

Fixed-way modes of urban transportation are characterized by higher initial costs and lower operating costs than flexible modes. As peak-hour transit passenger demands increase beyond 20,000 passengers per hour in a single corridor, the total costs of Bus Rapid Transit and Rail Rapid Transit systems become competitive.

Bus rapid transit systems can provide as much total capacity as rail rapid transit systems, but for the same passenger volumes they would require 15 times as many drivers. Thus as the transit passenger demand increases within a corridor, the lower operating costs of rail systems begin to off-set their higher initial costs. As the peak-hour transit passenger increases beyond 20,000 passengers per hour in a single corridor, the total cost for these two modes becomes competitive.

Areas of highly concentrated activities such as CBD's, airports, universities, etc. need an effective circulation system within the area in order to function effectively. Several such areas in the Coastal Zone have become so large and congested that the pedestrian mode alone can no longer adequately provide for circulation. Personal Rapid Transit or people-mover systems can provide effective movement of people within an area of highly concentrated activity.

Many forms of people-movers have been proposed recently including horizontal elevators, moving sidewalks, mini monorail trains, and small rubber-tired trams. All of these concepts are aimed at filling the gap between conventional automotive traffic and walking. They operate at speeds of 5 to 15 mph and most of them use remote power sources so that service can be provided directly into buildings through a network of passageways.

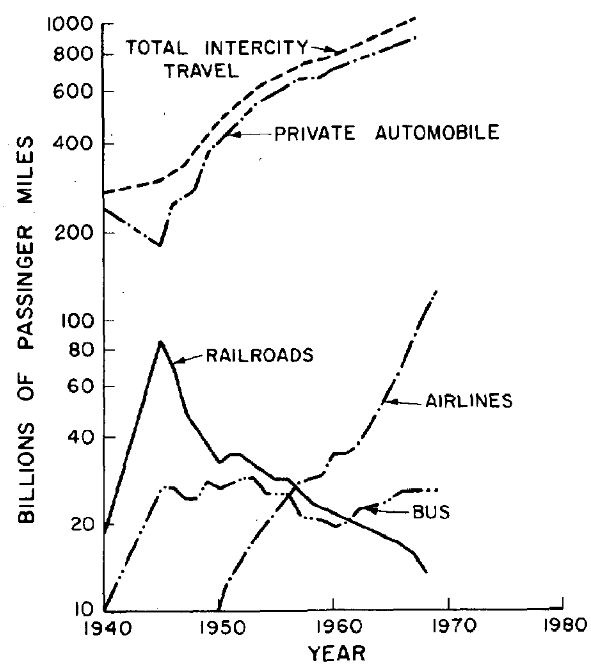
The movement of goods is an often overlooked part of the total transportation problem. Urban congestion results not only from the excess demands for the movement of people, but also from the extremely large demand for the movement of goods within the urban area. People do not seem to notice the vast amount of goods movement required to serve an area of concentrated activity such as a CBD, but it is monumential. A recent traffic study in Dallas showed that there were four times as many commercial trucks entering the CBD every day as there were total vehicles entering Love Field (15). When a talley is made of the total daily movement of food, beverages, mail, office supplies, newspaper, etc. within a CBD it is obvious that any reduction in congestion due to improved movement of people could easily be offset by continued uncoordinated movement of goods.

Very few solutions have been proposed for the problems of goods movement in urban areas. Some passive control measures (such as restricting deliveries to certain hours) might be effective temporarily, but eventually active measures must be taken. A central receiving dock might be established for the CBD and goods distributed using the people mover system during off-peak periods. Resupply of the central dock might be handled by the mass transportation system during off-peak periods. Whatever the final form of goods movement, plans for future urban transportation systems must consider this aspect of the total problem (16).

PERSON MOVEMENT

A quick look at historical trends in intercity passenger travel for the nation (see Figure III-5) yields some interesting observations concerning our existing and future intercity transportation needs. Since the advent of the automobile and the development of a paved highway network, Americans have depended upon the automobile for most of their intercity travel (approximately 90% of total travel is by automobile). The private automobile will probably continue to provide the bulk of intercity travel because it offers a level of convenience and a degree of flexibility that is unattainable with any form of common carriage.

FIGURE III-5 TRENDS IN INTERCITY PASSENGER TRAVEL IN U. S.



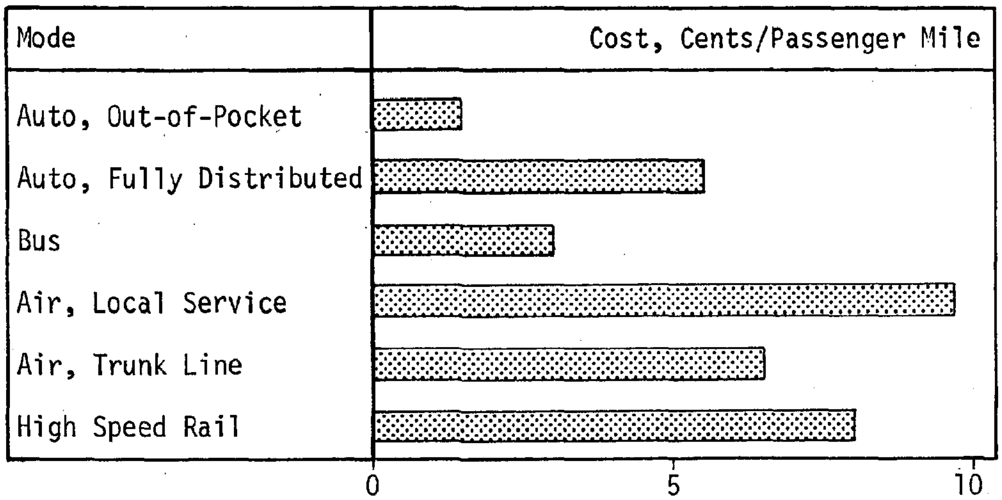
Source of Data: Reference 17

Historical trends in intercity travel in the U.S. show a continued dependence on private automobile made possible by increasing automobile ownership and improved highways. Rail travel has been replaced by air travel while bus travel has remained relatively constant.

Trends in intercity common carriage show that rail travel is being replaced by air travel while bus travel has remained relatively constant. Airlines and bus companies do not compete between all cities but the bulk of their passenger traffic occurs between cities served by both modes. This might indicate a demand for two types of intercity carriage: one that offers the best level-of-service and one that offers the lowest price. Apparently, there is very little demand for an inbetween type of service.

Relative costs and service characteristics of automobile, bus, airline, and high speed rail intercity travel are discussed in the following paragraphs. Conventional rail passenger service is not discussed further because it has effectively ceased in the Coastal Zone. High speed rail service, however, may possibly replace airlines as the preferred mode of travel on relatively short intercity trips. A comparison of the relative operating costs of these modes is presented in Figure III-6.

FIGURE III-6 AVERAGE COSTS OF INTERCITY PERSON MOVEMENT



Sources of Data: References 13, 18, 19, and 20

When only out-of-pocket costs are considered, the automobile is the lowest cost mode of intercity passenger travel. Bus is the least expensive form of common carriage and local air service is the most expensive. It appears that high speed rail could possibly replace air service on intercity trips of 300 miles or less.

In comparing the automobile to the other transport modes two different costs must be considered. The fully distributed cost includes all cost associated with owning and operating a vehicle. However, if the user already possesses an automobile, whether he is using the vehicle or not, he is paying such costs as insurance, depreciation, taxes, etc. Consequently, if he desires to take this car on a trip, the only additional expenses incurred will be gasoline and oil. These represent the out-of-pocket costs associated with any given trip and they provide the auto with a cost advantage over the other modes.

The automobile is best suited for relatively short intercity trips that require no more than one day of travel. It provides a level of flexibility and convenience unmatched by any other mode, particularly for recreational travel. The driver can depart from his own home and arrive directly at his destination, and the automobile provides him with a means of transportation while at his destination. For longer business trips, however, the additional time required as well as the added costs of food and lodging makes driving less attractive than flying.

Bus service provides a dependable but relatively slow means of intercity travel. Its lower cost makes it the choice for many people who do not own automobiles and cannot afford air travel. Special non-stop bus service between major cities, which are no more than 200 miles apart, can provide a suitable alternative to short-haul air service.

The airplane provides a relatively high level of service. People use the airplane for several reasons; 1) speed of travel, 2) the status, prestige, and comfort associated with air travel, and 3) the dependability of the service. Airplanes can operate economically with a rather low passenger demand since air travel requires no fixed facility costs between terminals. As a result, the airplane can serve many intercity desires which are not of sufficient magnitude to support high-speed rail service.

The cost of airline operations is significantly different for trunk line and local service. The average trip length served by trunk line operations is about 800 miles while local service trips are usually less than 300 miles. Of course, much of the traffic using local air service is going to or from a major airport for connections with trunk line air service. Nevertheless, for shorter trips, air service loses much of its attraction relative to other modes.

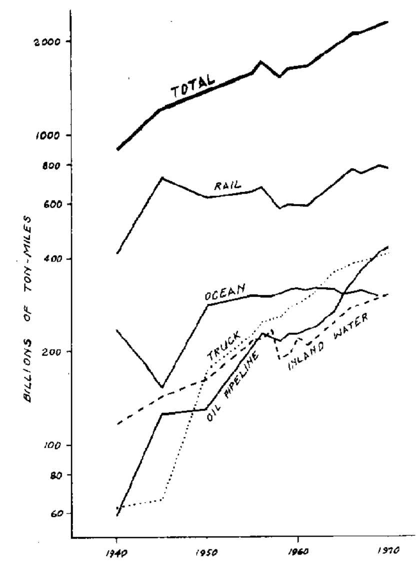
Recent operations of the Metroliner in the Northeast Corridor, and other high-speed trains, have demonstrated that this mode can effectively compete with short-haul air service. Trains operating at speeds of 100 to 150 miles per hour can provide a comparable level of service to airplanes. However, the facilities for high speed rail are very costly so that it is competitive cost-wise only in corridors which produce a substantial volume of intercity trips.

GOODS MOVEMENT

Nationwide trends in intercity transportation of goods, shown in Figure III-7, reflect a reasonably constant rate of increase totalling 150% over the last 30 years. This high rate of increase in total goods carried is expected to continue during the next 30 years. Also, there will probably be some further redistribution of traffic handled by the various modes as is indicated by these trends. Each mode has inherent characteristics that make it particularly well suited for certain types of traffic; therefore, they each should continue to carry significant portions of traffic in the future.

The intercity transportation system involved in the movement of goods in the Coastal Zone includes major elements of all modes. Water transportation modes carry a larger proportion of goods shipped from the Coastal Zone than is indicated by the national average. Pipelines also handle a larger than average share of goods movement. Several factors influence the shipper in selecting a mode to move his commodity. The major factors are the cost, the level of service, and the capacity provided by each mode.

FIGURE III-7 TRENDS IN INTERCITY GOODS MOVEMENT WITHIN THE USA



Source of Data: Reference 17

The total demand for goods movement has increased at a constant but rapid rate resulting in a 150% increase during the last 30 years. This trend is expected to continue during the next 30 years. There may be a continued redistribution of traffic between modes, but each mode existing today should continue to carry significant portions of traffic in the future.

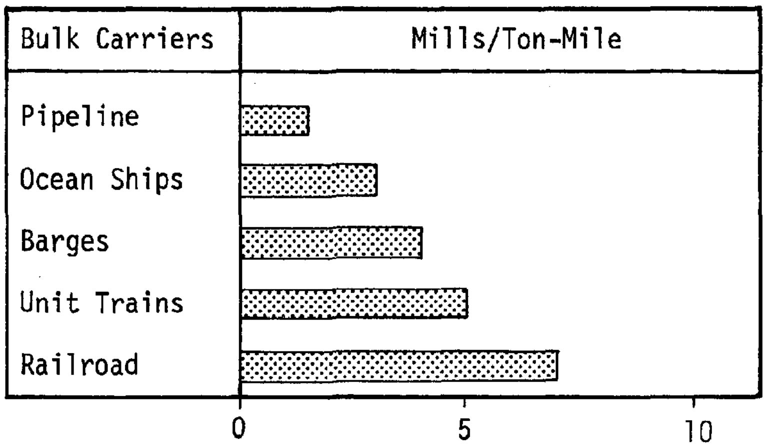
There are three basic costs involved in the transportation process: the terminal cost, the line-haul cost, and the inventory cost. Terminal costs include all handling costs associated with readying the shipment for transit as well as the billing and collecting costs. Line-haul costs are those which arise from carrying the shipment from its origin to its destination. These costs include the expense of running and maintaining the vehicle, the costs associated with constructing and maintaining any required right-of-way, and other allocation of overhead. Inventory costs are created since goods in transit are a form of working capital and, as a result, generate additional inventory costs due to time spent in transit.

Goods carried in intercity commerce generally fall into two categories: bulk goods and high-value goods. Bulk goods consist primarily of products from forests, mines and agriculture as well as petroleum products. These goods generally have a relatively low value and are usually transported in large shipments by rail, water or pipeline. High value goods consist mostly of manufactured items. Such goods can be moved profitably in relatively small shipments. Generally the speed of delivery is a matter of concern; consequently, many high-value goods are shipped by truck or even by air.

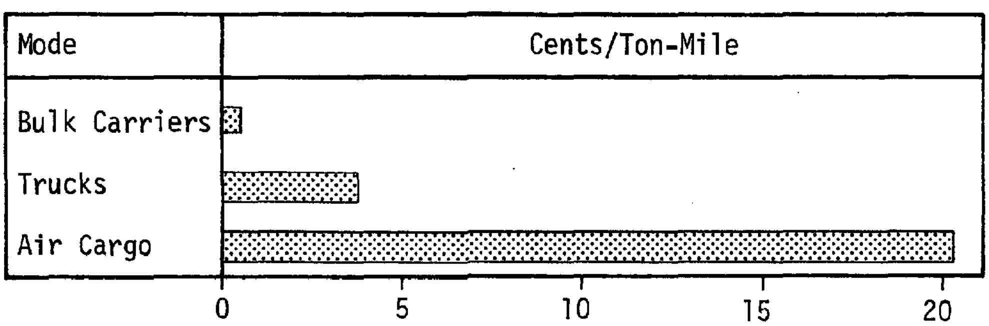
A comparison of the relative costs for goods movement by various modes of intercity transportation is presented in Figure III-8. These

FIGURE III-8 COMPARISON OF COSTS FOR GOODS MOVEMENT IN INTERCITY TRANSPORTATION

Bulk Goods



All Goods



Sources of Data: 19, 21, 22, and 23

Each mode of transportation is well suited for carrying certain types of traffic because of its inherent characteristics. Costs shown above are typical for each mode operating under reasonably favorable conditions. The relative cost position of each mode can be quite different when the shipper considers the movement of a certain commodity between two specific locations.

values represent typical costs for each mode operating under conditions well suited for its inherent advantages. The relative cost positions of each mode can be quite different when the movement of a certain commodity between two points is considered.

Pipelines are particularly well suited for the movement of fluids over relatively short distances when a continuous flow in one direction is desired. Under these conditions, pipelines offer the lowest cost mode of transportation. Costs increase significantly, however, when solids are transported by pipeline in slurry form. Pipelines require a large initial investment and the effective operating costs increase drastically if the diameter is not optimum for the desired throughput. Consequently, pipelines are usually designed and constructed to transport a specific commodity and flow rate between two points. Although pipelines can be the lowest cost mode of bulk transportation, they are also the least flexible mode.

Water transportation is characterized by relatively high terminal costs and extremely low line-haul costs. For long distance bulk movements, water transportation is competitive with pipeline. This is evidenced by the fact that most of the petroleum products shipped from the Coastal Zone to destinations over 500 miles away travel by water. The primary disadvantage of water transportation is its extremely slow delivery time as compared to other modes. Ocean transportation is less expensive than movement by barges on the inland waterway system; however, both modes of water travel are viable and they are extremely important to the Coastal Zone.

Railroads provide a reasonably rapid means of transporting bulk goods and they have the capability of moving a large variety of commodities. The extensive rail network of the nation makes rail the most flexible mode of bulk transportation. However, unless the origin and destination are both located on a rail siding, goods shipped by rail must also be carried by another mode. Due to the high terminal costs and low line-haul costs, costs of rail movement decrease as the distance traveled and tonnage shipped increase. In rare instances, the volume of goods shipped between two points is sufficient to justify the use of unit trains. This type of operation significantly reduces terminal costs and improves service enough to make rail competitive with any mode.

Trucks, operating on an extensive network of streets and highways, provide the most flexible form of goods movement. Trucks can normally pick up shipments at their point of origin and deliver them directly to their destination. This high degree of flexibility combined with relatively short delivery times yields a high level of service that makes trucking an extremely attractive mode for the shipment of high-value goods over relatively short distances despite its apparently higher cost. Trucking is characterized by a low terminal cost but a relatively high line-haul cost. Thus the attractiveness of trucking relative to other modes decreases as the length of haul increases.

The piggyback concept, loaded truck trailers riding on railroad flat cars, combines the flexibility of trucking with the low line-haul costs of rail service. The terminal costs associated with piggyback are less than those of rail but slightly higher than those for trucks. Thus it provides an attractive means of shipping goods over intermediate distances.

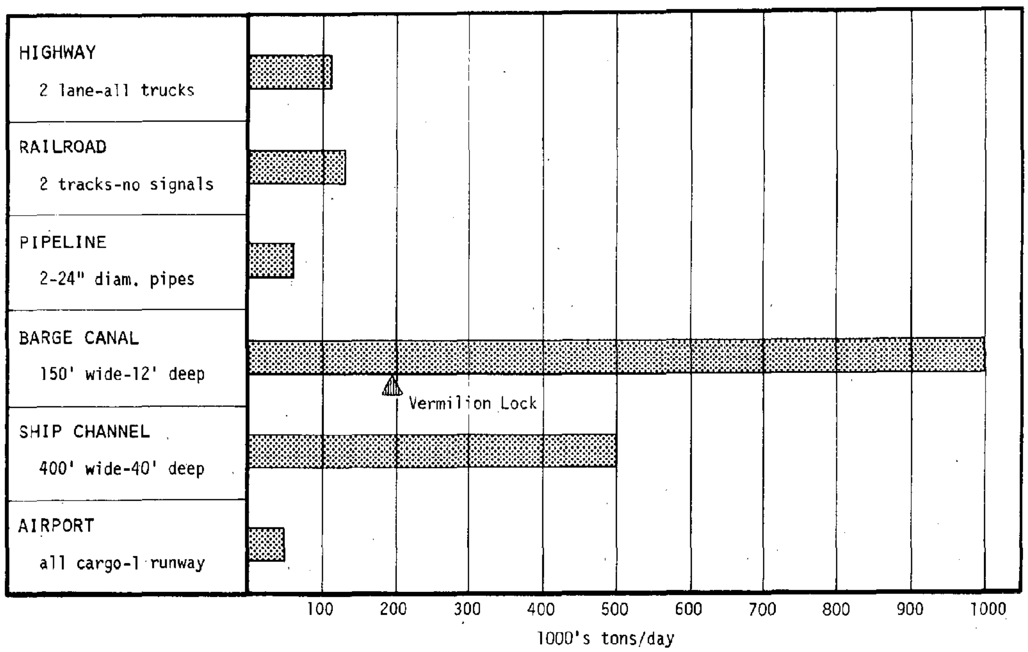
Presently less than 0.2% of total goods movement travels by air, but air service is the fastest growing form of goods movement. The number of ton-miles served by air-cargo has doubled in the last five years. The advent of the new wide-bodied jets provides the airlines with an even greater opportunity to expand their cargo operations. Despite its higher costs, air shipment provides a higher speed that makes it attractive for long-hauls of high-value and perishable commodities.

The demand for the intercity movement of goods has historically grown faster than population. The population of the Coastal Zone is expected to double in the next 30 years; consequently, the demand for intercity goods movement could triple. Undoubtedly, some new transportation facilities will have to be expanded to serve this increased demand. Relative capacities of different modes is a major consideration in identifying alternative means of providing for increased demands.

The modal capacities presented in Figure III-9 were calculated for a basic facility serving each mode that is characteristic of those currently existing in the Coastal Zone. Capacities of such facilities are determined by the maximum number of vehicles (assuming typical sizes and load distribution) that can safely use the facility. In most cases, capacities can be increased by installing traffic control systems, increasing the average vehicle load, and reducing the number of empty back-hauls.

This comparison vividly shows the higher capacities afforded by the two modes of water transportation. Barge canals, such as the Gulf Intracoastal Waterway, provide the highest capacity for goods movement. This extremely high capacity for a canal is somewhat misleading unless the constraints imposed by locks are considered. There are no locks on the Texas portion of the Gulf Intracoastal Waterway; however, almost all barge traffic entering or leaving Texas must pass through the Vermilion Lock in Louisiana. The ultimate capacity of this existing lock is calculated to be less than one-fifth the capacity of the open canal. Thus nothing could be gained by widening the canal unless the capacity of the locks can be increased drastically.

FIGURE III-9 COMPARISON OF MODAL CAPACITY FOR GOODS MOVEMENT



A comparison of the capacities of basic facilities vividly shows the higher capacities afforded by the two modes of water transportation. The extremely high capacity of a barge canal is somewhat misleading unless constraints imposed by locks are considered. Almost all barge traffic entering or leaving Texas must pass through Vermilion Lock in Louisiana and its ultimate capacity is calculated to be less than one-fifth that of the open canal.

MAJOR AREAS OF CONCERN

Mechanized transportation is more than just a convenience for man - it is essential for the survival of his society. Man cannot continue to live in cities and provide for his needs without an extensive, viable transportation system. Unfortunately, all modes of transportation must have some impact upon the environment; however, better facility design and improved propulsion systems can reduce the detrimental effects of new transportation systems. The first step toward improvement is logically a definition of the major areas of environmental concern relative to transportation systems.

Air Quality. Emissions from transportation vehicles contain several compounds which contaminate the atmosphere. Unburned hydrocarbons react with nitrogen oxides in the presence of sunlight to form smog. Carbon monoxide and lead compounds are poisonous to humans and other animal life. Huge volumes of carbon dioxide disturb the normal balance of the atmosphere. Particulate matter suspended in the air creates a haze and eventual fallout. Therefore, the effect of transportation systems on air quality is a major area of environmental concern.

The extent to which transportation systems contribute to air pollution is a source of much debate. A report released by the federal government based on data collected in 1965 stated that motor vehicles were responsible for 61% of the total annual air pollution tonnage. However, two scientists working with the same data concluded that on a relative toxicity basis, motor vehicles were responsible for only 12 percent of the nation's air pollution. A later federal study concluded that in 1968 the total transportation sector was responsible for 42% of the nation's air pollution (24).

The relative extent of air pollution from various sources is important in establishing priorities for concerted remedial actions. However, even if transportation systems are responsible for only a small percentage of the nation's total air pollution, they do produce emissions that damage the atmosphere. Air quality must be considered a major area of environmental concern as long as transportation systems can create a killing smog under certain atmospheric conditions.

Water Quality. Most transportation systems do not pollute the water directly, but fallout from the air can result in significant deteriorations in water quality. Water transportation systems do have a direct impact on water quality since ships and barges sometimes discharge pollutants into the water. Also, when operating in confined channels and canals, water vessels create severe water turbulence that can result in a deterioration in water quality. Bays and estuaries along the Texas coast play a vital role in the mariculture of the area so water quality is a major area of environmental concern for the Texas Coastal Zone.

Noise. Noise is usually defined as unwanted sound. In other words, it is a nuisance. Certainly, noise can be a nuisance, but prolonged exposures to high sound pressure levels can result in some hearing loss. Sound pressure levels produced by some transportation systems are compared to physiological effects in Table III-7. Obviously, transportation systems can produce sound pressure levels that are physically damaging so noise is also a major area of environmental concern.

TABLE III-7 PERCEIVED NOISE LEVELS

Physiological Effect	Noise Level, PNdB	Transportation Element
Pain	-140-	
		Jet-Liner on Takeoff
Some Hearing Loss	-110-	Unmuffled Truck Exhaust
Temporary Hearing Loss	- 90-	Motorcycles
Annoying	- 80-	Busy Street
(Normal Conversation)		
No Effects	- 70-	Automobile Traffic

Source: Reference 25

Noise is one area of environmental concern for transportation systems. Other major areas of concern include air quality, water quality, waste heat, drainage patterns, and land-use patterns.

Waste Heat. Because of a basic law of nature, engines can never be designed which effectively utilize all of the energy of combustion - some of it must be lost or wasted. Existing propulsion devices utilize less than 40% of the energy resulting from the combustion process. Thus, more than half of this energy is dumped into the environment as waste heat. Recent studies indicate that the average temperature levels of the world's atmosphere are gradually rising. This rise in temperature may be caused by the tremendous amount of waste heat generated by power plants, industrial plants, transportation systems, residential heating and air-conditioning, and other activities of man. Some scientists fear a "green-house" effect may cause the temperature levels to start rising more rapidly and that the results may be irreversable (26).

Effects of waste heat upon the environment and the resulting additional fuel requirements make the relative efficiency of transportation systems a matter of environmental concern. Of course, the efficiency of transportation systems is also a matter of economic concern. Therefore, waste heat is included as a major area of environmental concern.

Drainage. Construction of new transportation facilities change the characteristics of water runoff in the immediate area. The quantity of run-off usually increases and sometimes the drainage pattern is altered by changes in grades. If the effects of changes in drainage are not considered in the design of a facility, severe soil erosion and possible flooding can result. Therefore, drainage should be a major area of environmental concern in the design of transportation facilities.

Land-Use Patterns. Major transportation facilities can have a strong impact on existing and future land-use patterns in adjacent areas. The net result can be positive in nature, but if these effects are not considered in the design and location of the facility, the result can be disruptive to the overall urban environment. Existing and future land-use patterns should be a major area of environmental concern in the design of transportation facilities in or near urban areas.

Other Considerations. Transportation systems are sometimes condemned on several other "environmental" counts including visual pollution, litter and automobile junk yards. Although these problems are associated with transportation systems, they are not a direct result of the construction or operation of transportation facilities. Litter occurs along highways and streets, but it is generated by the people - not the automobiles. Billboards and large neon signs are located along major traffic facilities because of the large number of people using the facility. Automobile junk yards persist because of economic considerations that are external to the transportation system. Therefore, these problems have not been included as major areas of environmental concern for transportation systems.

COMPARISON OF MODES

Most studies of the relative impact of the various modes of transportation upon the environment have shown that the highway mode results in more environmental damage than the other modes. Part of this is due to the relative usage of the various modes. After all, highways provide for more than 90% of all person movement and about 50% of all goods movement in the nation. None of the studies conducted to date have tried to compare the relative impact of the modes based upon an equivalent level of activity.

Relative environmental impacts of various modes of transportation are compared subjectively in Table III-8. This comparison assumes normal operating conditions for each mode at an equivalent level of activity. Potential environmental damages that could result from major mishaps are not included in this evaluation. The possibility and relative severity of mishaps such as ships breaking up, pipelines rupturing, trains derailing, etc., are factors that should be considered in the design and operation of all modes of transportation.

TABLE III-8 RELATIVE ENVIRONMENTAL IMPACTS OF VARIOUS TRANSPORTATION MODES

Major Areas of	Mode of Transportation				
Environmental Concern	Highway	Air	Rail	Pipeline	Water
Air Quality	High	Medium	Medium	Low	Medium
Water Quality	Low	Low	Low	Low	High
Noise	Medium	High	Medium	Low	Low
Waste Heat	High	High	High	Medium	High
Drainage	High	Medium	High	Low	Low
Land-Use Patterns	High	Medium	High	Medium	High

All modes of transportation have some impact on the environment; however, corrective actions are being taken to minimize the severity of these impacts. Future transportation systems will be more compatible with the environment.

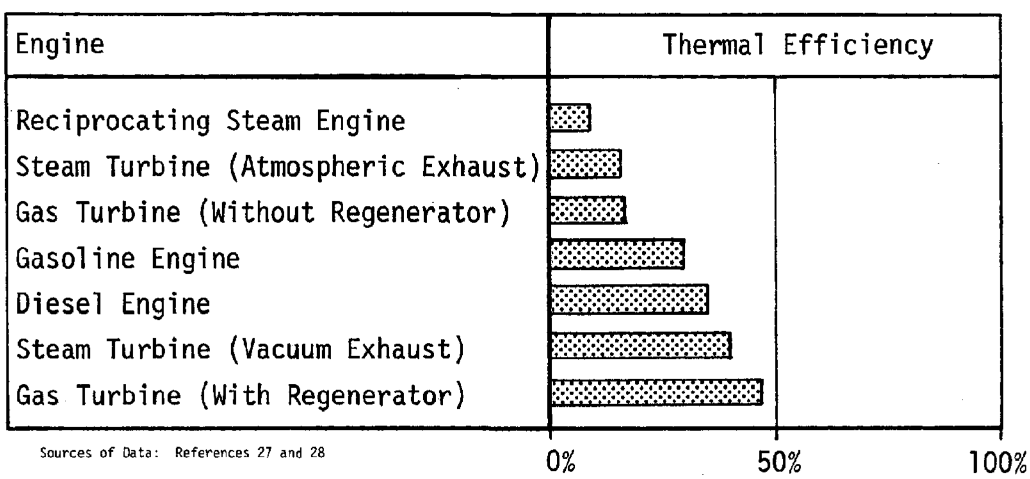
Corrective actions are already being taken to reduce the severity of most of these environmental impacts. Emission control devices are included on new automobiles. The designs of newer jet engines have significantly reduced their noise levels and exhaust emissions. Discharges from water transportation vehicles are controlled. Drainage and land-use considerations are included in the design of all new transportation facilities. Thus, transportation systems of the future will be more compatible with the environment.

The automobile is the most visible source of air pollution to the general public. Therefore, it has been the object of much criticism. Some people have proposed eliminating all automobiles or, at least, outlawing the internal combustion engine. However, there is no alternative mode of transportation available today that offers the degree of flexability and level of convenience that an automobile provides. Also, the urban form of American cities has been shaped by the automobile to such an extent that most of them cannot be served effectively by any other existing mode of transportation. Thus, it seems that a better strategy would be to seek ways to minimize the environmental effects of automobiles while new forms of transportation are being developed.

Exhaust from internal combustion engines, particularly gasoline engines, contains a higher percentage of harmful products than external combustion engines. Gasoline and Diesel engines might be replaced by reciprocating steam engines, steam turbines, gas turbines, or even battery powered electric motors. However, each of these alternatives have serious drawbacks.

Reciprocating steam engines can not achieve but about one-third the thermal efficiency obtainable with internal combustion engines (See Figure III-10). Stationary steam turbine engines, such as those used in electric power plants, achieve higher thermal efficiencies than

FIGURE III-10 RELATIVE THERMAL EFFICIENCIES OF ENGINES



Sources of Data: References 27 and 28

The internal combustion engine is one of the more efficient engines developed by man. Indeed, no existing engine can achieve better efficiencies over the broad range of operating conditions required of motor vehicle engines.

internal combustion engines, but much of this efficiency results from the vacuum portion of the cycle. Vacuum exhaust steam turbines are so large that they are impractical for automobiles. Steam turbines that exhaust to the atmosphere are less efficient than gasoline engines. Thus, steam engines do not appear to be suitable alternatives to the internal combustion engine.

Extensive efforts have been directed toward the development of a gas turbine for use in automobiles. In fact, Chrysler Corp. built and field tested a limited number of turbine powered cars in the early 1960's. However, a suitable regenerator has not yet been developed for use in automobiles, and without a regenerator, gas turbines are less efficient than internal combustion engines.

Recent efforts have been directed toward the development of battery-powered electric automobiles. Light-weight batteries which can provide power for sufficient range and speed have not yet been developed. Some of the higher performance batteries produce poisonous emissions so they are not suitable for urban use. Also, it should be recognized that this concept merely moves the source of pollution to the electric generation station.

Conversion of gasoline engines to operate on propane or liquified natural gas has also been proposed as a method of reducing pollution. These lighter hydrocarbon fuels burn to completion so that the only exhaust products are carbon dioxide and steam. They cause a slight loss in power but no loss in efficiency. However, the hazards associated with a possible rupturing of pressurized fuel tanks are serious considerations for vehicles operating in urban traffic. The availability of fuels is also a problem. Propane is a by product of gasoline plants, and the demand for natural gas is already taxing the supply.

The course of action now being pursued is aimed at reducing emissions from automobiles by installing pollution control devices and modifying designs when necessary. This course of action is already yielding encouraging results. Data from continuing monitoring tests indicate that the total amount of pollution produced by automobiles peaked in 1967 and has been declining since. Total emissions are expected to continue declining during the next few years as older cars go out of service (24).

Federal standards for 1975-1976 model automobiles require a 90% reduction in air pollutant emissions from the 1970-1971 levels. Cars produced after 1975 are required to maintain these low emission levels for a period of five years or 50,000 miles of operation. In order to meet these requirements after 50,000 miles of operation, newer low-mileage cars must have even lower levels of emissions. Data included in Table III-9 show that experimental models tested in 1971 are approaching the low-mileage targets. However, manufacturers may have difficulties in placing these experimental models into production.

TABLE III-9 EMISSION LEVELS OF FUTURE CARS

	Emissions, grams/mile		
	HC	CO	NO_x
1975 Standards:			
After 50,000 miles	0.41	3.4	3.0
Low-mileage targets	0.19	1.5	1.9
Experimental Vehicles in 1971:			
A	0.21	3.5	1.2
B	0.15	2.4	2.1
C	0.13	1.9	1.3
D	0.31	2.3	1.7
E	0.24	3.7	4.5

Source: Reference 29

Federal standards for cars built after 1975 require a 90% reduction from 1970 levels of air pollutant emissions. Experimental vehicles tested in 1971 are approaching these targets.

Individual cities can greatly reduce emissions from automobiles by improving traffic operations on city streets. Automobile emissions are almost four times greater under stop and go traffic operations than under normal freeway driving conditions. A comparison of relative emission levels under typical traffic operations on different types of streets is presented in Table III-10. This comparison shows that smoother flowing traffic conditions produce less pollution.

TABLE III-10 EFFECTS OF TRAFFIC CONDITIONS ON AUTOMOBILE EMISSIONS

Typical Traffic Conditions On Facilities	Relative Emission Levels
Freeways	1.0
Arterial Streets	2.0
Local Streets	2.4
Central Business District	3.8

Source: Reference 30

Stop and go driving conditions greatly increase the emissions produced by automobiles. Improvements in traffic flow conditions can significantly reduce air pollution.

Individual automobile owners can also do much to help reduce air pollution by keeping their cars well-tuned and timed for efficiency rather than power. Most new automobiles being bought today have much more power than is needed for normal urban driving. Indeed, some of today's automobiles have better performance characteristics than the best fighter planes of World War II (See Table III-11). If the individual truly wants to do something about air pollution, he can stop buying such over-powered cars. Power loadings of 20 to 30 lbs/hp should be sufficient for all urban driving conditions.

TABLE III-11 POWER LOADINGS OF VARIOUS TRANSPORTATION VEHICLES

Vehicle	Power Loading lbs/hp
Aircraft:	
W.W. II Fighter Planes	7-9
DC-7 Airliner	10
DC-4 Airliner	12
Automobiles (1970):	
High Performance Models	7-10
Average Models	15-20
Mini-Compacts	30-50
Buses	40-100
Trucks	50-400
Railroad Trains	500-1000
Ocean-Going Ships	2000-4000

Sources of Data: References 31, 32, and 33

Some cars on the streets today have better performance characteristics than the best fighter planes of World War II. If the individual really wants to do something about air pollution, he can stop buying such over-powered cars. Also, he can keep his car well-tuned and timed for efficiency rather than power.

EXISTING TRANSPORTATION IN THE TEXAS COASTAL ZONE

THE TRANSPORTATION INDUSTRY

The entire economic structure of the State of Texas is founded upon transportation. The importance of transportation becomes apparent when the four largest sectors of the Texas economy are identified (See Table IV-1). Three of the four are entirely dependent upon transportation for their value. In other words, petroleum and agricultural products are of value at their point of origin if they can not be transported to a market. It becomes obvious, then, that a healthy transportation industry is essential to a healthy economy.

TABLE IV-1 MAJOR ECONOMIC SECTORS IN TEXAS

Sector	Annual Output, Billions of Dollars
1. Petroleum Refining	6.6
2. Petroleum Production	4.4
3. Banking and Insurance	1.8
4. Agriculture	1.3

Source: Reference 34

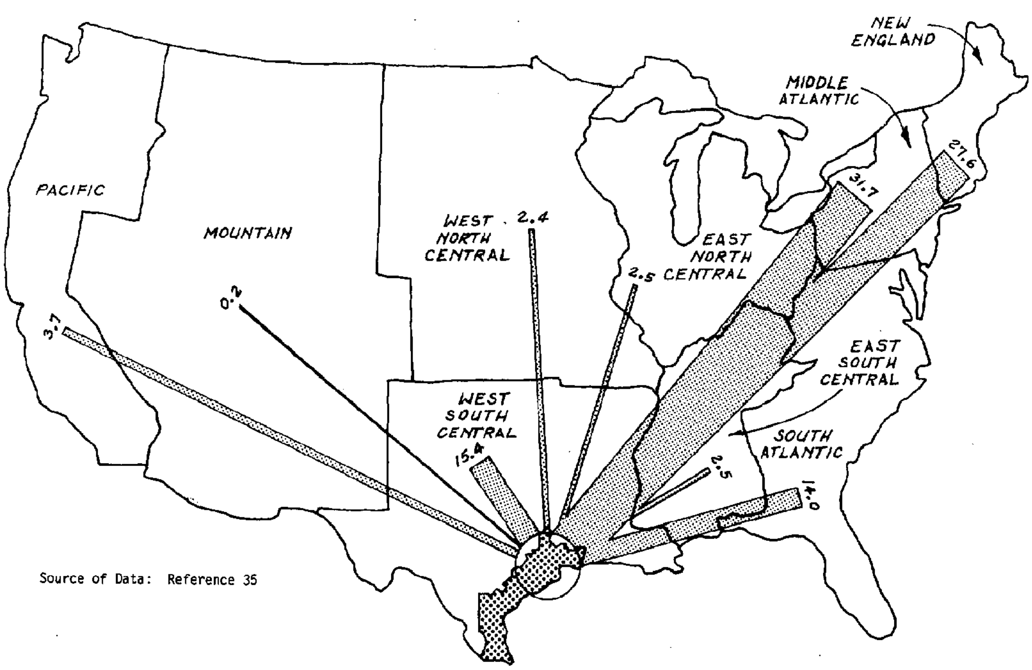
Three of the top economic sectors in Texas are entirely dependent upon transportation for their value. In other words, petroleum and agricultural products are of little value if they can not be transported to a market. A healthy transportation industry is essential to a healthy economy.

The transportation industry itself is a major sector of the Coastal Zone's economy. Nationally, the transportation industry carries an annual average of 20 to 25 tons of goods per person in intercity commerce. In 1970, the transportaion industry in the Coastal Zone handled over 110 tons per resident - more than 4 times the national average.

The importance of the Coastal Zone's transportation industry is indicated by the data collected in the 1967 Census of Transportation (35) (36). Unfortunately, this survey was limited to major production areas, as defined by the U. S. Department of Commerce; and to statewide totals. Production Area 21 (which includes the metropolitan areas of Houston, Beaumont-Port Arthur-Orange, and Galveston-Texas City) is the only production area in the Coastal Zone. However, data for this production area should be indicative of the region as a whole.

These data show that Production Area 21 ships 76% of all tons of goods shipped from Texas. If petroleum and coal products are subtracted from the totals, Production Area 21 still ships 40% of the State's total. Shipments from the Coastal Zone go to all areas of the United States, but the bulk of these shipments are destined for markets in the northeastern portion of the country as indicated in Figure IV-1. Obviously the transportation industry of the Coastal Zone connects shippers in the area with a widely dispersed market.

FIGURE IV-1 DESTINATIONS OF GOODS SHIPPED FROM PRODUCTION AREA 21 (PERCENT OF TONS)



Source of Data: Reference 35

The transportation industry connects Coastal Zone shippers to widely dispersed markets throughout the nation. However the bulk of the shipments are destined for the northeastern portion of the country.

Data in Table IV-2 show the distribution by distances for goods shipped from Production Area 21 in 1963 and 1967. More than two-thirds of the goods shipped from the area traveled over 1000 miles. However, there appears to be a trend toward shorter distances shipments. When petroleum and coal products are subtracted from the totals, the distribution of distances is decidedly different and the trend toward shorter-length shipments is even more pronounced.

TABLE IV-2 DISTANCE DISTRIBUTION OF SHIPMENTS FROM PRODUCTION AREA 21 (PERCENT OF TONS)

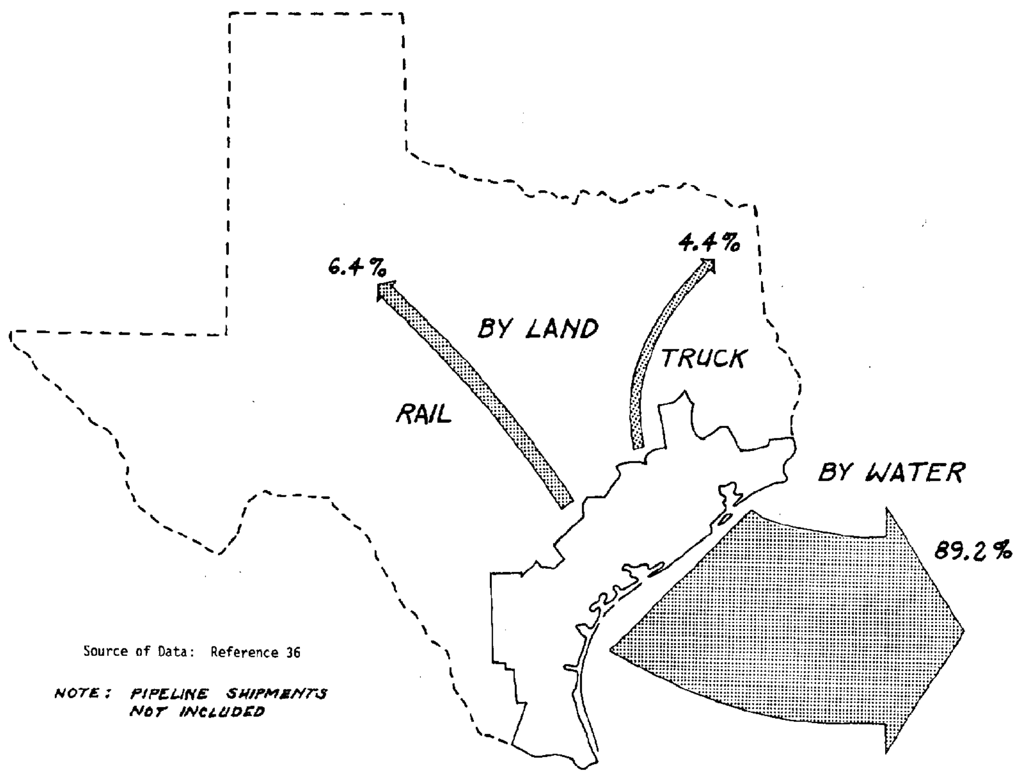
Distance Of Shipment	All Commodities		All Commodities Except Petroleum And Coal Products	
	1967	1963	1967	1963
Under 100 Miles	5.3	4.0	20.3	17.5
100-199	4.1	2.1	13.6	7.3
200-299	4.0	2.3	13.6	5.5
300-499	3.2	4.7	7.3	2.8
500-999	16.5	12.7	20.6	10.8
1,000-1,499	47.8	62.8	18.5	55.0
1,500 Miles and Over	19.1	11.4	6.1	1.1
Total	100.0	100.0	100.0	100.0

Source: Reference 36

More than two-thirds of the goods shipped from the Coastal Zone travel over 1000 miles. However, there seems to be a trend toward shorter-length shipments. When all petroleum and coal products are subtracted from the total, this trend is more evident.

Perhaps the most surprising factor indicated by these data is the relative importance of water transportation to the Coastal Zone and to Texas. More than 120 million tons of goods are shipped by water from Texas ports each year. As depicted in Figure IV-2, this represents almost 90% of all shipments from the Coastal Zone. Unfortunately, pipeline shipments are not included in these figures; nevertheless, the relative importance of water transportation is surprising even for a coastal region.

FIGURE IV-2 MODAL DISTRIBUTION OF GOODS SHIPPED FROM THE TEXAS COASTAL ZONE



Few Texans realize the importance of water transportation to the Coastal Zone and to Texas. Over 120 million tons of goods are shipped by water from Texas ports each year. This represents almost 90% of all shipments from the Coastal Zone and almost 75% of all goods shipped from the State as a whole.

Most Texans seem to think of Texas as a huge land area with an excellant highway and railroad system. Their only thoughts of the coast concern its excellent fishing and swimming opportunities. Hence, the data shown in Table IV-3 astounds them. Almost three-fourths of all goods shipped from the State as a whole travel by water. Of course, the bulk of this water traffic carries petroleum products so the modal distribution looks quite different when petroleum and coal products are substracted from the totals. This resulting 16% is more nearly what most Texans would guess as the percentage of water transportation.

TABLE IV-3 MODAL DISTRIBUTION OF GOODS SHIPPED FROM TEXAS

Means Of Transport	All Commodities 1967	All Commodities Except Petroleum And Coal Products 1967
Rail	11.7	39.9
Common Motor Truck	8.4	23.9
Private Motor Truck	6.0	19.9
Air	-	-
Water	73.8	15.9
Other	.1	.4
Total	100.0	100.0

Source: Reference 36

Texans don't seem to think of Texas as a seafaring state, yet, almost three-fourths of all goods shipped from the State travel by water. The Coastal Zone serves as the focal point of transportation for the entire State.

The total transportation system serving the Coastal Zone of Texas includes major elements of all existing modes (highway, rail, air, pipeline, inland waterway, and ocean transport). If the Coastal Zone is to continue to thrive, each mode of transportation must remain viable. Problems facing its transportation industry should be of serious concern not only to the residents of the Coastal Zone but to the entire State.

PORT ACTIVITY

Texas ports handled a total of 192 million tons of goods in 1970. The Port of Houston is the third busiest port in the nation - exceeded only by New York and New Orleans. The ports at Beaumont, Port Arthur, Orange, and Sabine Pass all use the Sabine-Neches Waterway, and if their activity is combined, they form the fourth busiest port in the nation. Indeed, the data in Table IV-4 show that Texas rivals New York in waterborne commerce. The totals for the State of New York include activity on the New Jersey side of the Port of New York-New Jersey; hence, Texas may well be the leading seafaring state in the nation.

TABLE IV-4 TONNAGE HANDLED BY U. S. PORTS IN 1968

PORTS	MILLION TONS/YEAR
1. New York - New Jersey	175
2. New Orleans	114
3. Houston	58
4. Philadelphia	49
SHIP CHANNELS IN TEXAS	
1. Houston Ship Channel	77
2. Sabine-Neches Waterway	55
STATES	
1. New York	192
2. Texas	185
3. Louisiana	167

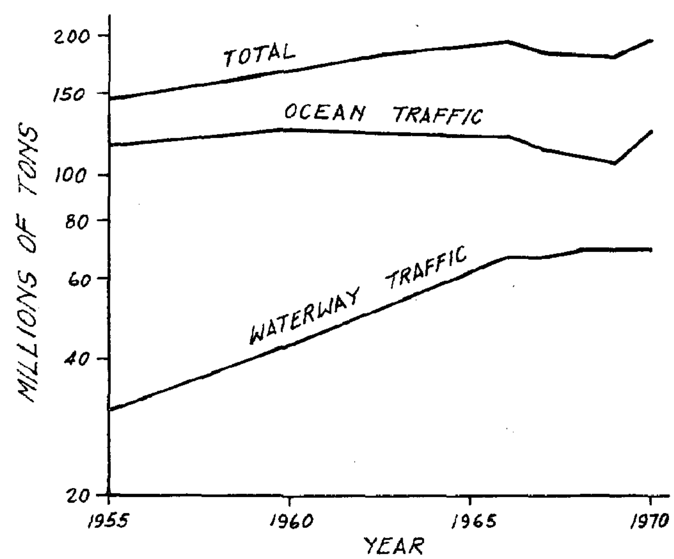
Source: Reference 37

Water transportation is extremely important to the State of Texas, and Texas maritime activities are important to the nation. Texas rivals New York as the premier seafaring state in the nation. Yet, Texas has no state agency specifically concerned with water transportation.

Considering the relative importance of water transportation to the State and the relative importance of Texas maritime activities to the nation, it seems ironical that Texas has a state agency specifically concerned with every mode except water transportation. The individual ports must try to solve their problems and to work with federal agencies without assistance or support from the State. When the water transportation industry suffers from unsolved problems related to Gulf and waterway traffic, the economy of the State also suffers. Thus, the viability of water transportation is a matter of concern to the entire State of Texas.

The total tons of goods handled by Texas ports increased steadily until 1967 when a slump in traffic occurred. As shown in Figure IV-3, the total port activity in 1970 was barely back to what it was in 1966. A generally sluggish economy was probably largely responsible for this slump. However, some disturbing possibilities are indicated by these long term trends. Traffic using the inland waterway system increased rapidly (about 7% per year) for more than 15 years, until 1967, and then leveled off. Some of this leveling off in traffic is probably the result of severe congestion experienced on portions of the Gulf Intracoastal Waterway. (This problem is discussed in greater detail in the section concerning waterway traffic.) Even though a significant recovery was made between 1969 and 1970, total ocean traffic has not increased in the last ten years.

FIGURE IV-3 TRENDS IN ACTIVITY AT TEXAS PORTS

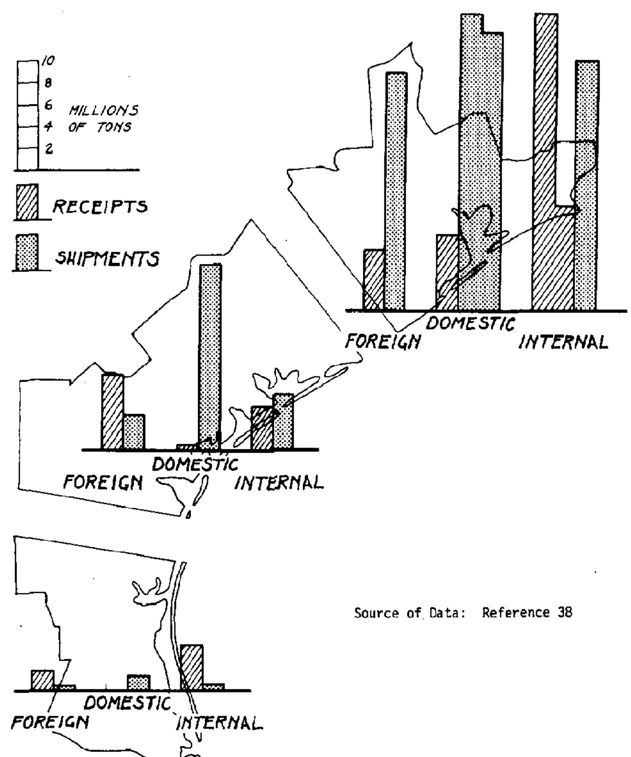


Source of Data: Reference 38

Total activity at Texas ports increased steadily until 1967 when a severe slump occurred. Much of this slump was probably due to a sluggish economy; however, some disturbing possibilities are indicated by these trends.

Texas ports handle three types of waterborne traffic - foreign, domestic coastwise, and internal. Of course, foreign traffic is carried between nations on ocean-going ships. Domestic coastwise traffic is also carried on ocean-going ships but only between ports in the United States. Internal traffic is carried in barges along the inland waterway system. A comparison of the volumes of goods included in each type of waterborne traffic at Texas ports is presented in Figure IV-4. Of the total 192 million tons of goods handled, 123 million tons were shipped out (64%) and 69 million tons were received (36%). This indicates the role that water transportation plays in the exportation of goods from the Texas Coastal Zone.

FIGURE IV-4 TEXAS PORT ACTIVITY - 1970



Source of Data: Reference 38

Texas ports handled a total of 192 million tons of goods in 1970. The bulk of this traffic was in shipments, about 64%, which indicates the role that water transportation plays in the exportation of goods from the Texas Coastal Zone.

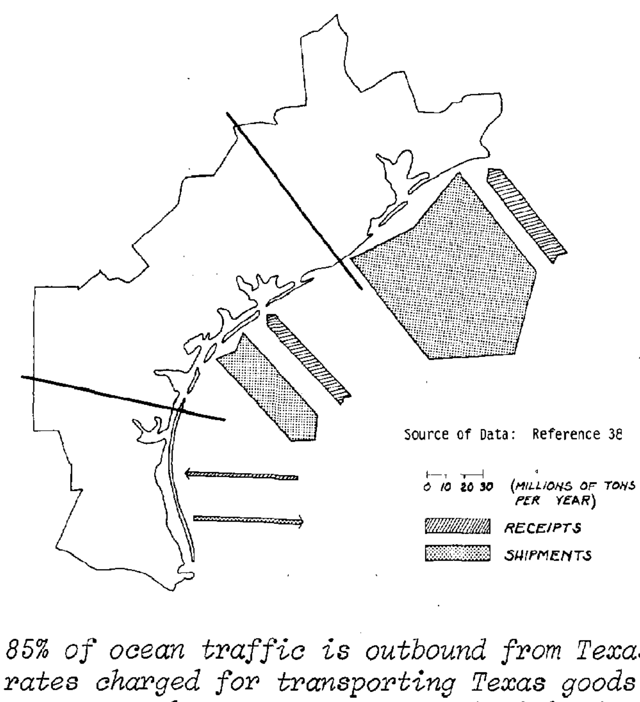
OCEAN TRAFFIC

The term "ocean traffic" is used here to denote all goods entering or leaving Texas ports on ocean-going ships - an annual average of about 120 million tons. Almost two-thirds of this traffic is domestic coastwise commerce most of which travels between Texas and the northeastern seaboard. The remaining 40 million tons is in foreign trade primarily with nations in South America and Europe. Thus, almost all of these ships travel between Texas ports and other ports on the Atlantic Ocean.

The total tonnage of ocean traffic handled by Texas ports has not increased during the past 10 years despite a significant growth in the population and industrial activity in the Coastal Zone. The reasons for this lack of growth are probably many and varied, but one contributing factor must be the problems that hinder ocean traffic at Texas ports. Several of these problems are discussed in the following paragraphs.

One significant problem is the severe imbalance of flow for ocean-going vessels (See Figure IV-5). More than 85% of the ocean traffic is outbound from the Texas Coastal Zone. This means that nearly all

FIGURE IV-5 IMBALANCE OF FLOW IN OCEAN TRAFFIC



More than 85% of ocean traffic is outbound from Texas ports. Thus, the rates charged for transporting Texas goods must be sufficient to cover the cost of an empty back-haul.

of the ships carrying Texas goods out must return empty. Hence, the rates charged for transporting these goods must cover the cost of the entire voyage rather than just half of it. Of course, the specialized design of modern ships tends to limit the types of cargos they can carry, but if back-haul traffic were available, they could be modified to handle it.

Traffic congestion in the ship channels also causes a problem for ocean traffic - particularly in the Houston Ship Channel and the Sabine-Neches Waterway. These channels are not always busy, but severe congestion does occur during peak-periods - just as it does on streets and highways. In fact, several collisions between ships have occurred in the Houston Ship Channel in recent years. Of course, merchant ships are not the only vessels using these channels. Barges, fishing trawlers, ferries, and recreational vessels also contribute to the congestion. Traffic control systems can alleviate this problem somewhat, and the Houston Ship Channel is one of 14 in the nation currently being considered by the Coast Guard for a traffic control system - after enabling legislation is passed (39).

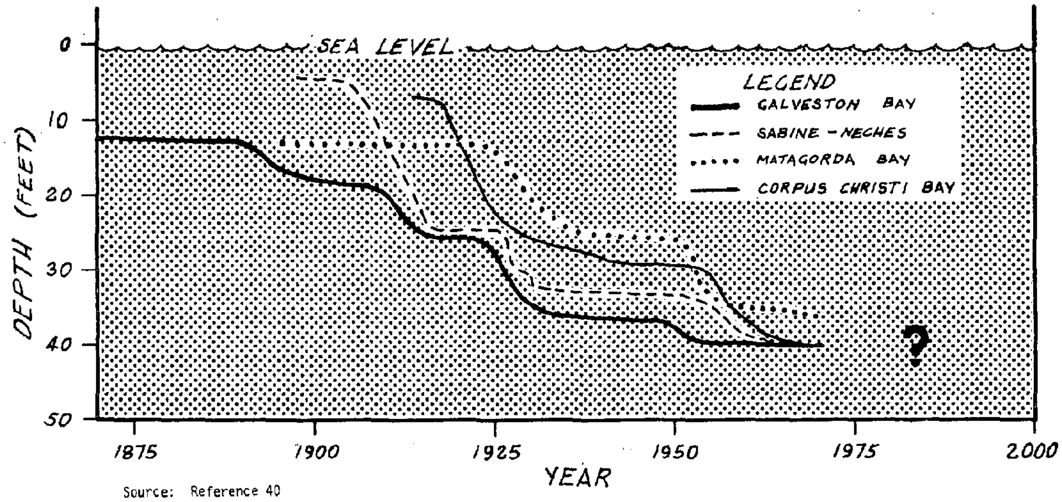
Limited channel depths have presented problems of ocean traffic at Texas ports for more than a century. Surveys by Commodore Moore of the Texas Navy in 1841 showed that both Galveston Bay and Matagorda Bay had natural channel depths of 12 feet - the deepest in Texas. Hence, most of the ocean traffic serving Texas in the third quarter of the nineteenth century docked at either Galveston or Indianola (40).

Houston was located at the supposed "head of navigation" of Buffalo Bayou in 1836. The natural water depth of 6 feet was hardly sufficient for most ships at that time even though the famed Constitution did sail up the Bayou to Houston in 1837. Houston set the pattern for all Texas ports by beginning channel improvements in 1840. Channel improvement became a way of life along the Texas coast before the end of the century. The aggregate effect of these efforts to increase channel depths is depicted in Figure IV-6. Current channel depths at major Texas ports are shown in Figure IV-7.

Even with such intensive efforts to increase them, channel depths to Texas ports have consistantly lagged the ever-increasing drafts of large ocean-going ships. Increases in ship sizes have never been as rapid as in the past 10 years; therefore, present channel depths become less adequate each year.

Almost half of the nation's petro-chemical industry and almost one-fourth of its refining capacity is concentrated in the Texas Coastal Zone. Consequently, the bulk of the tonnage in ocean traffic is liquid petroleum products carried in ocean tankers. The size of tankers has been increasing even faster than other ships during the last ten years.

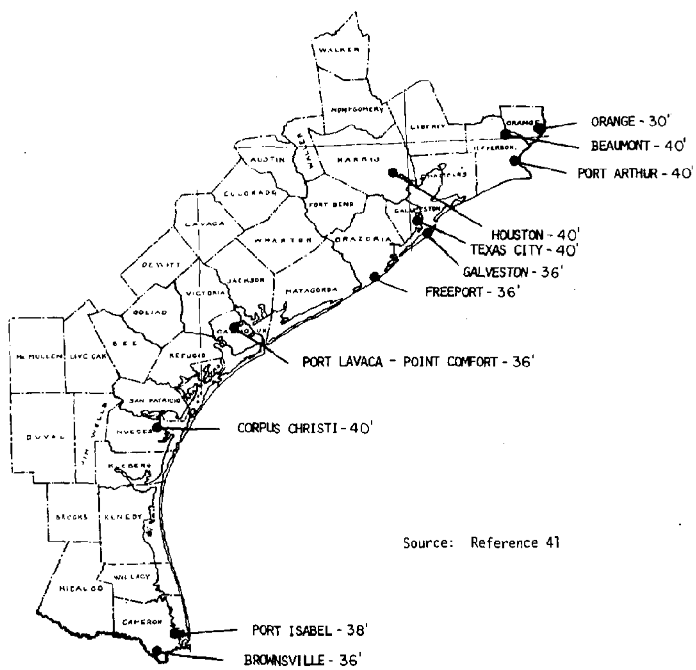
FIGURE IV-6 HISTORICAL INCREASES IN CHANNEL DEPTHS TO TEXAS BAYS



Source: Reference 40

Channel improvement has been a way of life along the Texas coast since the late 1800's. Yet, channel depths have consistantly lagged behind the ever-increasing drafts of large ocean-going ships.

FIGURE IV-7 CHANNEL DEPTHS IN 1970



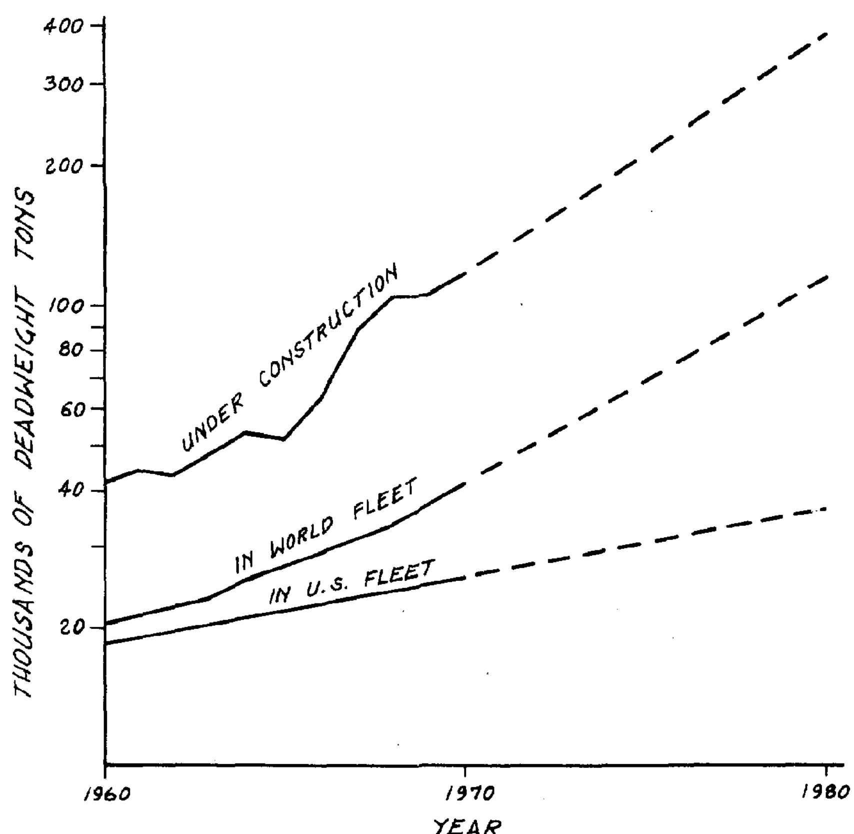
Source: Reference 41

Forty feet is the maximum channel depth along the Texas coast today. This is barely deep enough to serve the "average" size tanker in the world fleet today.

Recent trends in the "average" size of tankers are shown in Figure IV-8. The size of the average tanker under construction increased from 41,000 tons in 1960 to 116,000 tons in 1970. Two tankers exceeding 400,000 tons are now under construction and one 500,000 ton tanker is on order. As these giants become operational, there is a corresponding increase in the average size ship in the fleet. The average size tanker operating in the world fleet in 1970 was 42,000 tons. This is about as large a ship as the current channel depths can serve. Obviously, some dramatic actions are needed if Texas ports are to be able to serve future ships.

Note - See Section VI Future Alternatives: Super-Draft Port for more detailed information concerning ship sizes.

FIGURE IV-8 TRENDS IN AVERAGE SIZE OF TANKER SHIPS



Source of Data: Reference 42

The size of the average tanker under construction increased from 41,000 tons in 1960 to 116,000 tons in 1970. As these giants become operational, the average size tanker in the fleet also increases. Dramatic actions are needed if Texas ports are to be able to serve future ships.

INLAND WATERWAY TRAFFIC

The Gulf Intracoastal Waterway extends from Brownsville, Texas to Apalachee Bay, Florida. Its 1113 miles of canals, of which 423 miles are in Texas, connects all ports on the Gulf of Mexico to more than 6000 miles of inland waterway centering on the Mississippi River. Dimensions of the Texas portion of the canal are as follows (43):

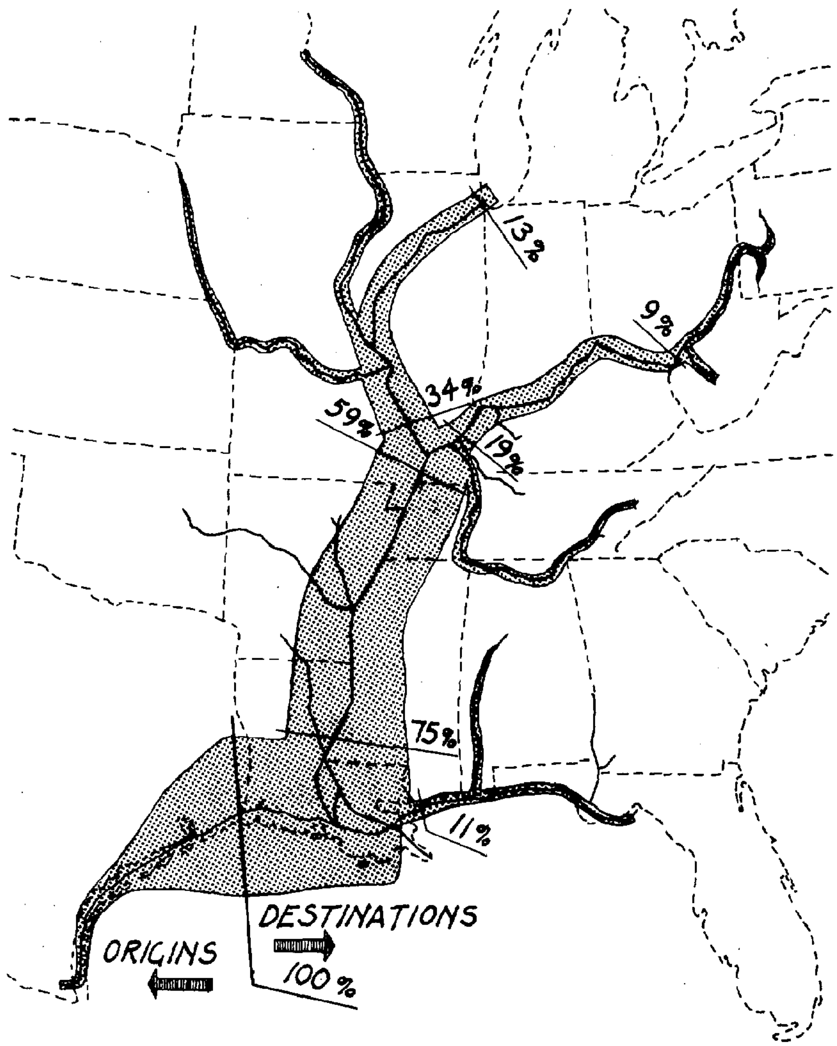
Brownsville to Galveston	12' deep x 125' wide
Galveston to Sabine Lake	16' deep x 150' wide.

All portions of the canal in Texas are essentially at sealevel so locks are not required. However, to reach the Mississippi River, Texas goods must pass through several locks in Louisiana.

Almost 70 million tons of goods were loaded onto or unloaded off of barges at Texas ports each year from 1967 to 1970. Inland waterway traffic in Texas increased rapidly from 1950 until 1967. In fact, more than 4 out of every 5 additional tons of waterborne traffic developed during the past 15 years have been due to the canal. The recent leveling off in inland waterway traffic (refer to Figure IV-3, page IV-7) may be largely due to congestion at the locks on the Louisiana portion of the canal. As peculiar as it may seem, conditions on the Louisiana portion of the canal have a strong impact on Texas waterway traffic.

About 36 million tons of waterway traffic crossed the Texas-Louisiana border in 1970. Some 60% of this traffic (approximately 22 million tons) was coming into Texas from various places. The far-reaching nature of inland waterway traffic is reflected by the distribution map for goods shipped from Texas presented in Figure IV-9. More than 75% of the 14.4 million tons of goods shipped from Texas was designed for points north of Baton Rouge on the Mississippi River system. Almost 60% of these goods went beyond the junction of the Ohio River with final destination as far away as Pittsburgh, Chicago, and Minneapolis.

FIGURE IV-9 MOVEMENT OF TEXAS GOODS ON INLAND WATERWAYS



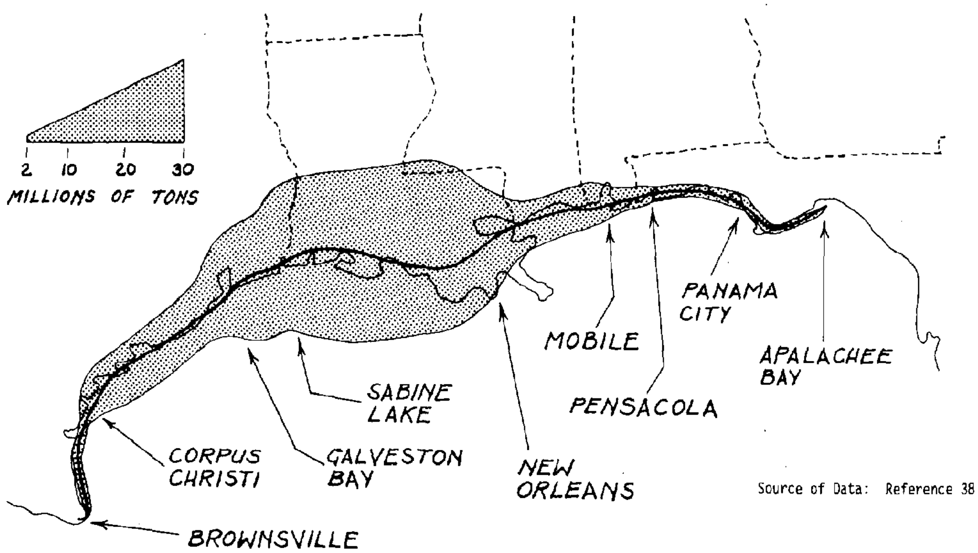
Source of Data: Reference 38

About 36 million tons of goods crossed the Texas-Louisiana border on the inland waterway in 1970. Shipments from Texas went to such far-flung markets as Pittsburgh, Chicago, and Minneapolis. All of this traffic must pass through several locks between the Mississippi River and Texas.

Obviously the section of canal in Louisiana links the Texas coastal area to extensive market areas on the Mississippi-Ohio River system. Relative traffic volumes for various segments of the Gulf Intracoastal Waterway, depicted in Figure IV-10, show the Louisiana segment to be the most heavily traveled. A total of 65 million tons of goods were carried by barges in this portion of the canal in 1970. Some of this traffic is local, but more than 36 million tons of it was going to or from Texas. Several locks along this portion of the waterway system are severely restricting the flow of traffic. Some barges have to wait 24 to 30 hours to pass through a lock. The total delays at locks can more than double the normal travel time between Sabine Lake and the Mississippi River. Thus, traffic congestion and delays at these locks in Louisiana can certainly deter future increases in inland waterway traffic in Texas.

> *<u>Note</u> - See Section VI Future Alternatives: Inland Waterway System for more detailed information concerning waterway traffic and lock capacities.*

FIGURE IV-10 TRAFFIC VOLUMES ON GULF INTRACOASTAL WATERWAY IN 1970



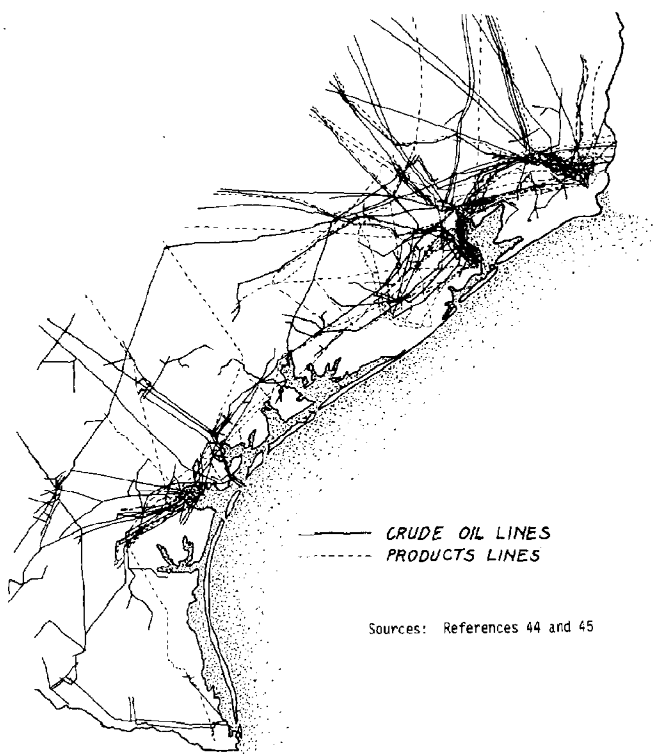
Source of Data: Reference 38

A total of 65 million tons of goods travel over the Louisiana segment of the canal. More than 36 million tons of this traffic is going to or from Texas. Locks along this segment cause severe delays which can deter future growth in waterway traffic in Texas.

PIPELINES

The Texas Coastal Zone presently has a greater concentration of pipelines than any similar size area in the world. This is not too surprising considering the vast petroleum resources contained within the Coastal Zone. The intensity of pipeline development within the region is indicated by the map in Figure IV-11 showing crude oil and petroleum products lines. Numerous natural gas pipelines also criss-cross the zone, but they are not included on the map. Most of the pipelines shown range from 6" diameter to 12" diameter; however, some are as large as 20" diameter and one is 36" diameter.

FIGURE IV-11 PETROLEUM PIPELINES IN THE TEXAS COASTAL ZONE

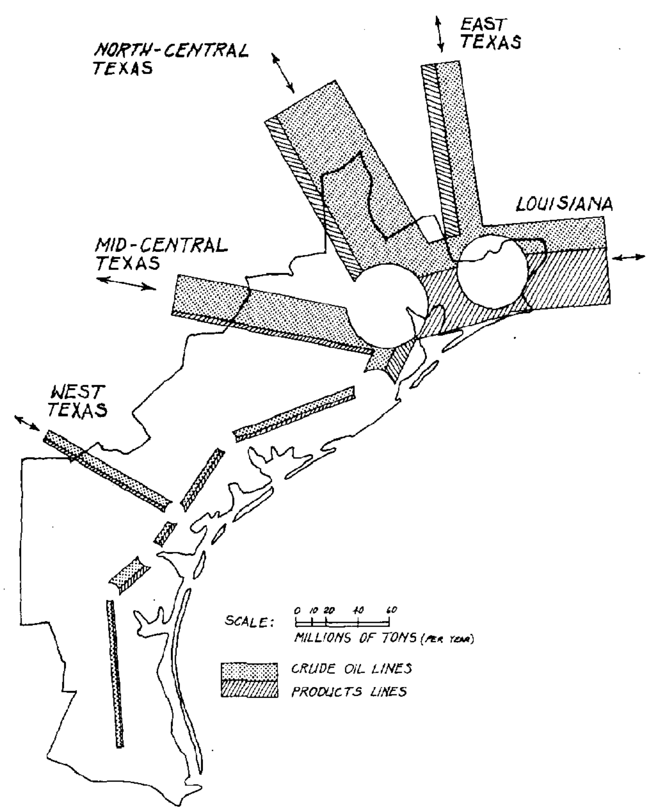


The Texas Coastal Zone has the highest density of pipelines in the world. Diameters of these petroleum pipelines vary from 4" to 36". Numerous natural gas pipelines also criss-cross the zone.

These petroleum pipelines transport a tremendous volume of goods every year. The capacity of all pipelines within identifiable corridors is depicted in Figure IV-12. The total capacity of pipelines entering or leaving the Coastal Zone is sufficient to transport more than 150 million tons of crude oil and petroleum products each year.

Sizeable increases in pipeline capacity will probably be needed if petroleum resources in the off-shore areas of Texas are developed in the future. However, as the population of the Texas Coastal Zone increases, locating and constructing additional pipelines will become increasingly more difficult. Of course, additional pipelines can probably be constructed within existing pipeline right-of-ways providing future needs lie within the same corridor.

FIGURE IV-12 CAPACITIES OF MAJOR PIPELINE CORRIDORS



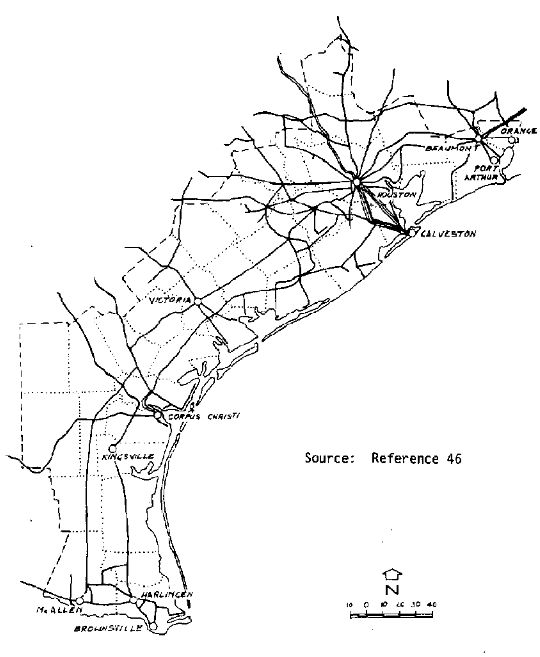
The total capacity of pipelines entering and leaving the Texas Coastal Zone is sufficient to transport more than 150 million tons of crude oil and petroleum products each year.

RAIL TRANSPORTATION

The Texas Coastal Zone is served by an extensive network of railroads that connect the region to the rest of the State and the nation. The 2989 miles of main-line tracks, shown in Figure IV-13, represent more than 21% of all railroad mileage in Texas. Indeed, the Coastal Zone was the birthplace of the Texas railroad system - every mile of railroad track that was built in Texas prior to the Civil War was in the Coastal Zone (47).

Unfortunately, statistical data concerning rail movements in limited regions of a state are scarce. Based upon the limited data available, a total of 55 million tons of rail freight is estimated to originate, terminate, or pass through the Coastal Zone each year. This represents about 28% of all rail freight tonnage reported by Texas railroads. The bulk of this rail traffic is estimated to be in corridors connecting the Coastal Zone to other regions.

FIGURE IV-13 RAIL LINES IN THE TEXAS COASTAL ZONE

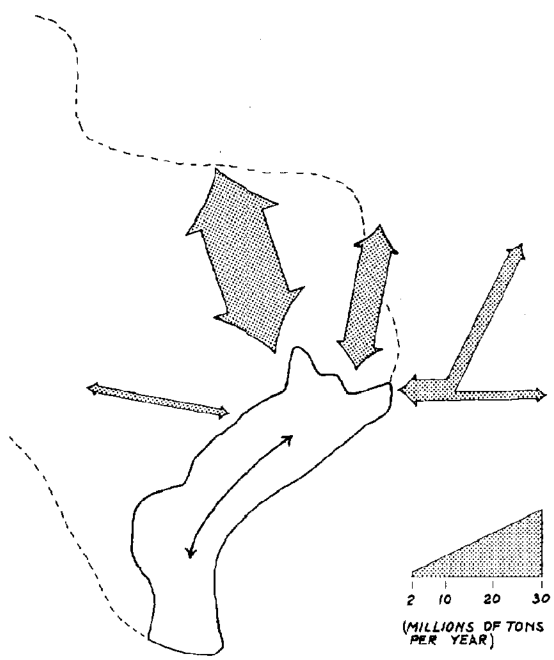


An extensive network of 2989 miles of main-line railroads serves the Texas Coastal Zone. Excellent rail connections link the Coastal Zone to the rest of the State and the nation.

A comparison of the estimated traffic volumes in major rail corridors serving the Coastal Zone is presented in Figure IV-14. The heaviest rail traffic occurs in the corridor connecting Houston to the Dallas-Ft. Worth area and points north. An estimated 21 million tons per year are carried in this corridor. This represents less than 20% of the total capacity provided by existing rail facilities in the corridor.

None of the rail corridors serving the Coastal Zone are presently operating at more than 20% of the basic capacity provided by the rail lines. If needed in the future, the basic capacity can be greatly increased through signalization and centralized traffic control (50). Consequently, it appears that no new main-line rail facilities will be needed in the Coastal Zone in the foreseeable future. Indeed, rail service might be improved by consolidating traffic and eliminating duplicate facilities.

FIGURE IV-14 ESTIMATED TRAFFIC VOLUMES IN MAJOR RAIL CORRIDORS

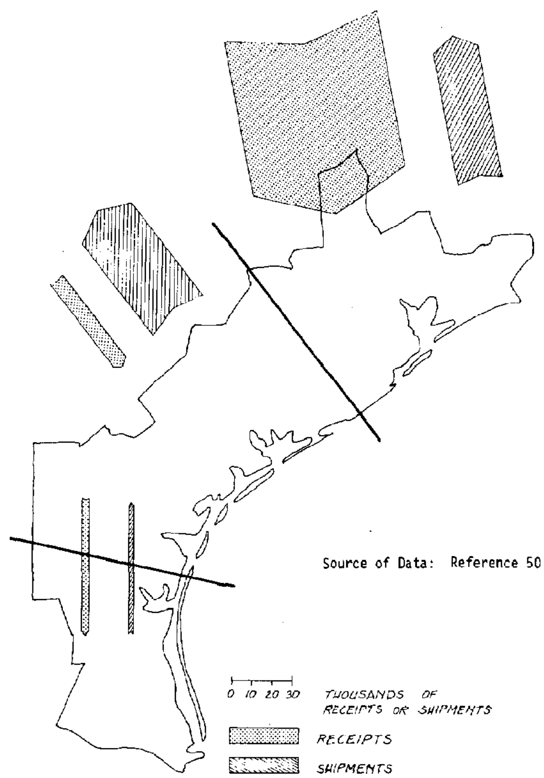


Sources of Data: References 35, 36, 48, and 49

A total of 55 million tons of rail freight is estimated to originate, terminate, or pass through the Coastal Zone each year. Even so, none of the corridors appear to be operating at more than 20% of available capacity.

Railroads play a major role in supporting Texas ports by transporting goods to and from the coast. Every major port is served by at least one railroad, and most ports are served by several rail lines. The imbalance of rail traffic to the Coastal Zone, illustrated in Figure IV-15, is indicative of this role. Large volumes of goods are carried into the ports in the northern segment of the zone resulting in a net inflow. Railroads carry several million tons of alumina from ports in the central segment to aluminum plants located inland, resulting in a net outflow. If the flow of ocean traffic is balanced in the future, it will probably help to balance rail traffic.

FIGURE IV-15 IMBALANCE OF RAIL TRAFFIC

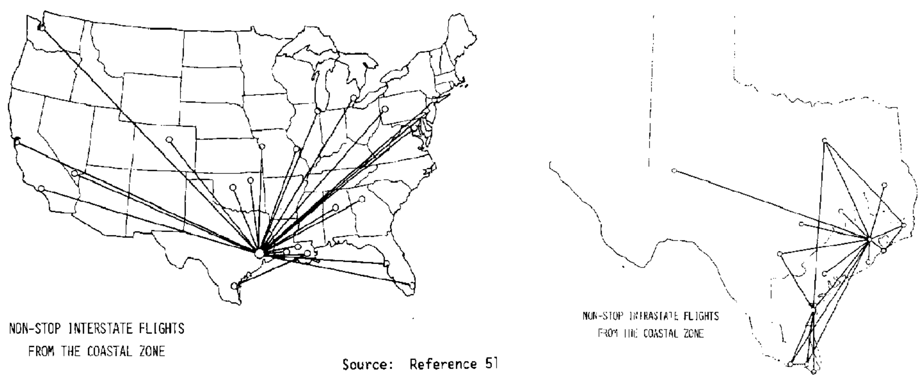


Imbalances in rail traffic to the Coastal Zone result in higher cost operations. Part of this imbalance, is due to the role that railroads play in supporting the ports.

PASSENGER TRAVEL

Eight airports in the Coastal Zone are presently served by scheduled air passenger operations. Scheduled non-stop flights, both intrastate and interstate, from these airports are shown in Figure IV-16. All other Coastal Zone airports have flights to Houston where connections can be made to most major airports in the nation.

FIGURE IV-16 AIRLINE SERVICE FROM COASTAL ZONE AIRPORTS



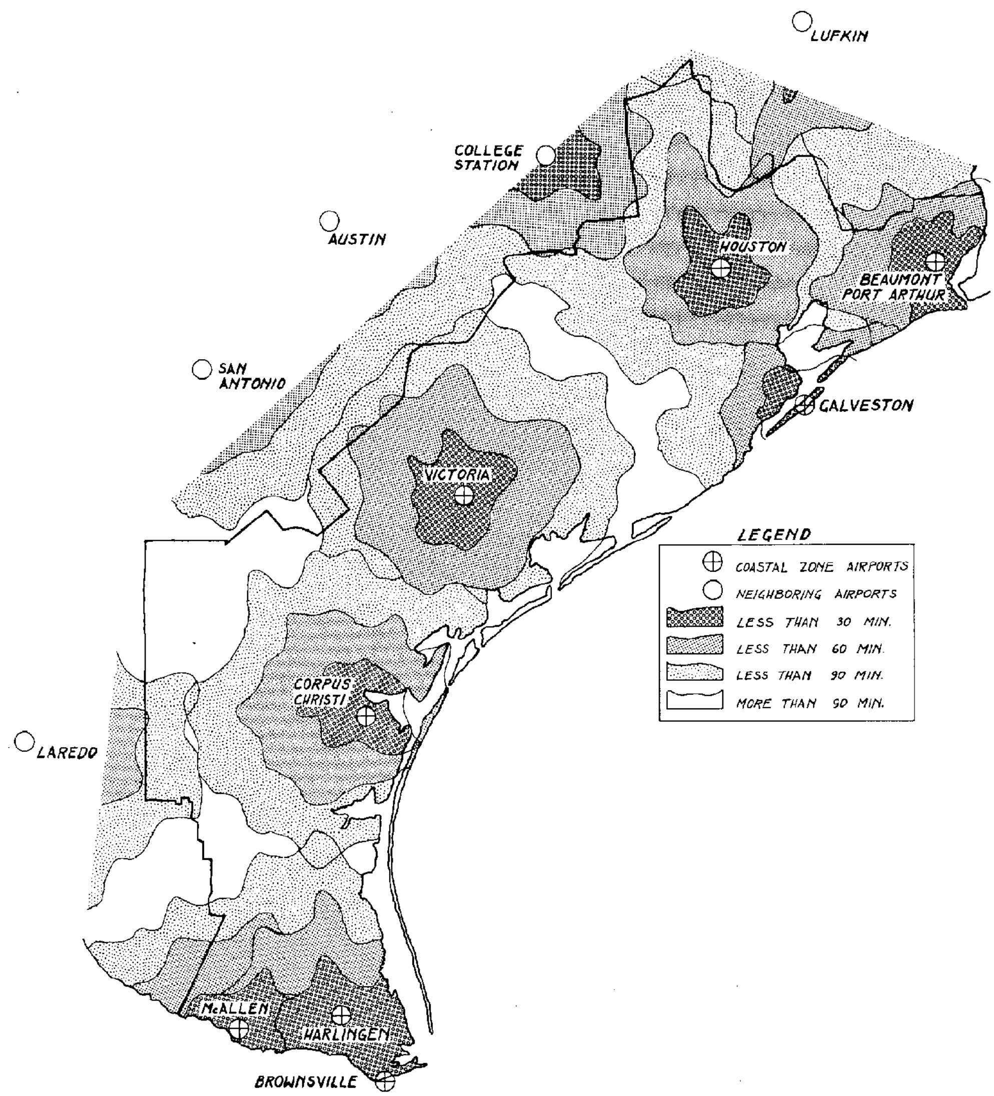
Source: Reference 51

Eight major airports in the Coastal Zone presently have scheduled airline service. All of these airports have flights to Houston where connections can be made to most major airports in the nation.

Nationally, air passenger travel increased ten times over between 1950 and 1970. Air travel from Coastal Zone airports has increased similarly. Almost 3 million passengers boarded planes at these airports in 1970. If recent trends continue, this total will increase to 30 million by 1990. Numerous airport improvements have been necessitated during the past twenty years by increased passenger traffic and changing aircraft requirements. Similar airport improvements will likely be required during the next twenty years.

The time required to drive to an airport has become a significant portion of the total travel time for modern airline trips. An analysis of average driving times required to reach the various airports shows that very few areas of the Coastal Zone are more than 1 1/2 hours from an air-carrier airport (See Figure IV-17). However, this situation will probably worsen as urban areas increase in the future.

FIGURE IV-17 GROUND ACCESS TIMES TO COASTAL ZONE AIRPORTS



The time required to drive to an airport has become an appreciable portion of the total travel time for modern airline trips. Very few areas of the Coastal Zone are presently more than 1 1/2 hours from an airport. However, this condition will probably worsen as urban areas continue to increase in the future.

AIR CARGO

In 1970, a total of 35 thousand tons of goods were shipped by air cargo from Coastal Zone airports (See Table IV-5). This is an insignificant portion of the total goods movement activity; however, air cargo is the fastest growing form of goods movement. If recent growth trends continue, the Coastal Zone will ship about one million tons by air in 1990. This total will still be less than one-half of one percent of all goods shipped, but it will be enough to require substantial improvements to goods handling facilities at existing airports.

TABLE IV-5 AIR CARGO ORIGINATING AT COASTAL ZONE AIRPORTS IN 1970

Air Port	Tonnage	Percent Of Total
Beaumont/Port Arthur	518.4	1.5
Brownsville	180.2	.5
Corpus Christi	1,403.7	4.0
Galveston	34.0	0.1
Harlingen	213.3	0.6
Houston	32,515.3	92.4
Mission/McAllen/Edinburgh	285.1	0.8
Victoria	22.5	0.1
Total	35,172.5	100.0

Source: Reference 52

Air cargo is the fastest growing form of goods movement. If recent trends continue, the Coastal Zone will ship about one million tons by air in 1990. Substantial improvements of goods handling facilities will be required to handle this traffic.

HIGHWAY TRANSPORTATION

Highways form the backbone of the intercity and urban transportation systems serving the person movement needs of the Coastal Zone. An extensive network of about 12,000 miles of freeways, highways, and farm-to-market roads criss-cross the Coastal Zone. Traffic volumes on the major highways in 1970 are depicted in Figure IV-18. Traffic volumes on most of these facilities are less than half the current capacity in most rural areas. However, traffic volumes increase rapidly as the highways approach urban areas. Extensive highway and street construction will be required to serve the projected growth in urban population during the next 30 years.

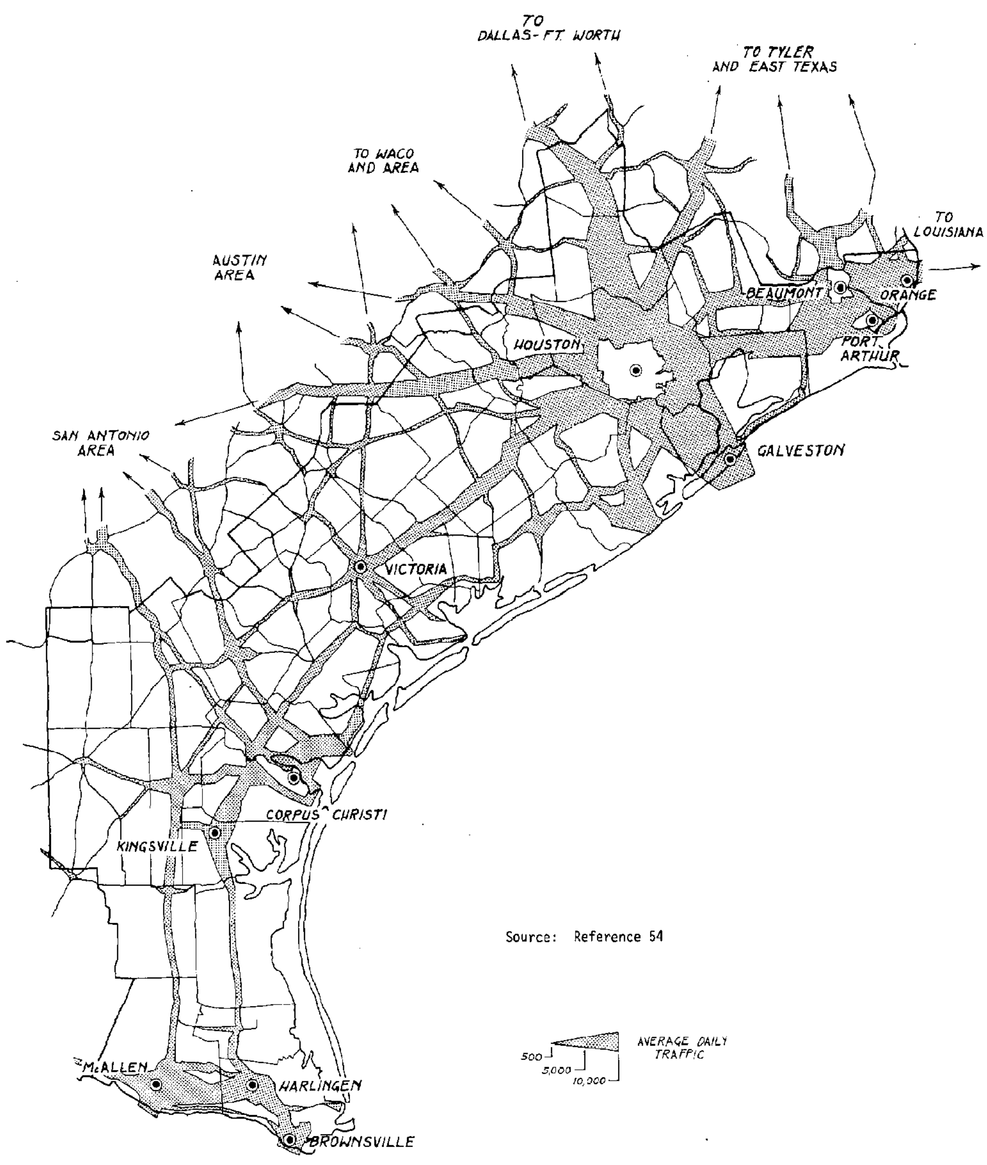
The average composition of vehicular traffic on rural highways in this area is as follows (53):

Passenger vehicles	75%
Pick-ups and pannels	13%
Motor trucks	12%
	100%.

About two-thirds of the large motor trucks are loaded with an average load of almost 10 tons of goods. The remaining one-third of the trucks are making empty back-hauls. Thus, an imbalance of flow also plagues trucking operations in the Coastal Zone.

Estimates of the annual volume of goods moved by trucks over certain highways in the Coastal Zone are listed in Table IV-6. A total of about 10.5 million tons of goods are trucked along highways leading northwest out of Houston. This compares to an estimated 21 million tons of goods moving by rail in the same corridor. However, more goods are carried into and out of the Lower Rio Grande Valley by truck than by rail. These estimates indicate that trucking provides a significant segment of the goods movement capability in the Coastal Zone.

FIGURE IV-18 1970 TRAFFIC VOLUMES ON COASTAL ZONE HIGHWAYS



The Coastal Zone is served by an extensive network of about 12,000 miles of freeways, highways, and farm-to-market roads. Current traffic volumes on most of these facilities are less than half of capacity in most rural areas; however, traffic volumes increase rapidly as the highways approach urban areas. Extensive highway and street construction will be required to serve the projected growth in urban population.

TABLE IV-6 ESTIMATED VOLUMES OF GOODS MOVED BY TRUCKS

Facility and Location	Millions of Tons/Year
1. U.S. 290 near Waller	4.3
2. Interstate 45 near Conroe	6.2
Total Corridor Northwest of Houston	10.5
3. U.S. 281 near Falfurrias	1.7
4. U.S. 77 near Riviera	1.6
Total Corridor to Rio Grande Valley	3.3

Trucking provides a significant segment of the goods movement capability in the Coastal Zone. The total tonnage carried by trucks rivals that carried by rail in some corridors.

Motor vehicles operating on streets and freeways provide almost all of the urban transportation in Coastal Zone cities. All of these cities have developed at average population densities that are compatible with an automobile-based transportation system. However, the cities have been hard-pressed to provide new and improved facilities fast enough to keep up with the rapidly increasing demand for urban travel. The cities will face even greater challenges in the future.

Major arterial streets and freeways usually constitute less than 20% of the total street mileage, but they handle more than 80% of the total urban travel. Arterial street and freeway systems of various urban areas in the Coastal Zone are compared in Table IV-7. The total mileage in these systems will probably have to be more than doubled during the next 30 years. Even so, the larger urban areas will probably need some form of mass transportation to supplement the automobile-based urban transportation system.

TABLE IV-7 URBAN ARTERIAL STREET AND FREEWAY SYSTEMS

	Arterial Streets		Freeways	
Urban Area	Pattern	Miles	Pattern	Miles
Houston	Grid	1200	Radial-Circumferential	165
Beaumont-Port Arthur-Orange	Grid	300	Triangular	60
Corpus Christi	Grid	150	Linear	40
Rio Grande Valley	Grid	150	Linear	80
Galveston-Texas City	Grid	100	Linear	35
Total	-	1900	-	380

Arterial streets and freeways usually constitute less than 20% of the total street mileage, but they handle more than 80% of the urban trips. Urban travel demands will probably triple in the next 30 years. The larger urban areas will need to supplement the automobile-based transportation system with some form of mass transportation.

Ownership of motor vehicles, especially automobiles, has increased from one vehicle for every 2.2 persons in 1960 to one vehicle for every 1.7 persons in 1970. Indeed, in some urban areas in the Coastal Zone there are now more registered motor vehicles than licensed drivers. This increase in automobile ownership has been accompanied by a corresponding increase in propensity to travel. Studies in other Texas cities show that the average number of daily auto trips per person has increased about 50% over the past ten years. Hence, the demand for urban travel has increased much faster than population.

Total urban population in the Coastal Zone is expected to double during the next 30 years - an additional 3 million persons. If these cities continue to develop at average population densities of about 2500 persons per square mile, an additional 1200 square miles of land area will be developed. This new development will require more than 3000 miles of major arterial streets and freeways as well as 15,000 miles of local and collector streets. Additionally, many miles of existing arterial streets will need to be replaced with better facilities.

As surprising as it may seem, the percentage of urban land area required for transportation facilities has actually gone down in recent years despite dramatic increases in urban travel. Approximately 26% of the land area is devoted to streets in newer auto-oriented developments while more than 35% is devoted to streets and alleys in areas developed before the automobile. Land-use characteristics of Coastal Zone cities are compared to the average for all Texas cities and the national average in Table IV-8.

Existing railroad lines require approximately 6% of the overall developed land in Coastal Zone cities. These railroads are actually a part of the intercity transportation system rather than the urban transportation system. No significant increases in railroad lines are expected during the next 30 years; however, it may be beneficial of some of the cities if portions of these rail lines are relocated.

TABLE IV-8 LAND USE CHARACTERISTICS OF URBAN AREAS

Land Use	Percentage Of Developed Land Area: Coastal Zone Cities	Texas Cities	National Average
Residential	39	37	37
Commercial	4	4	3
Industrial	10	5	5
Public & Semi-Public	11	12	17
Streets and Alleys	30	38	33
Other Transportation	6	4	5
Total	100	100	100

Source of Data: Reference 15

All transportation facilities presently occupy about 36% of the total land area in Coastal Zone cities. Newer developments require less land area for transportation so this percentage should decrease in the future.

COMPARISON OF THE NORTHEAST CORRIDOR AND THE TEXAS COASTAL ZONE

GENERAL CHARACTERISTICS

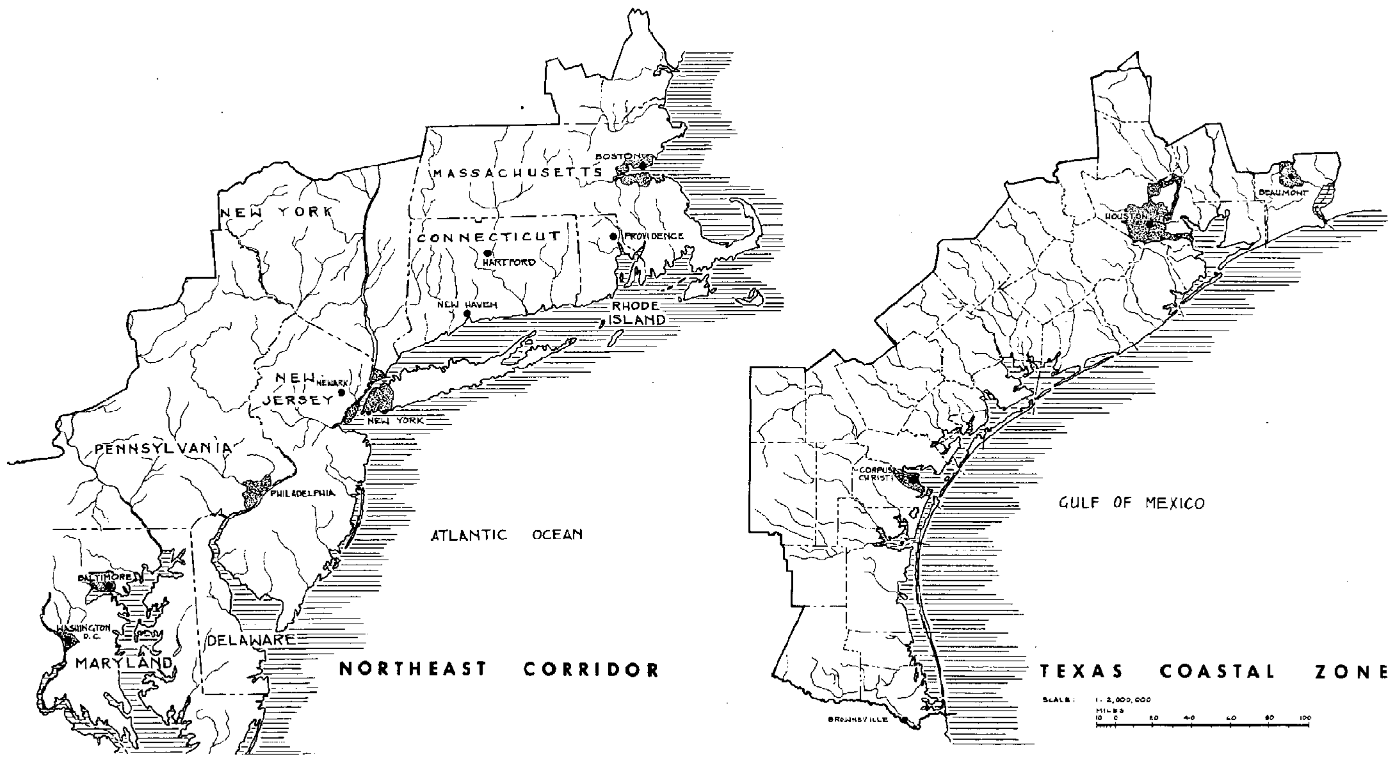
The Northeast Corridor stretches from Washington, D.C. to Boston and includes such cities as Baltimore, Philadelphia, Newark, and New York City. More than 20% of the nation's population is concentrated in this region which includes less than 2% of the nation's land area. It is not surprising, then, that the Northeast Corridor is facing some of the most severe urban and transportation problems in the nation. It is surprising, however, to realize that the Texas Coastal Zone resembles the Northeast Corridor in many ways now and might possibly look even more like it in the future. Thus a comparison of these two regions can provide information that will be useful in helping the Texas Coastal Zone to avoid many of the problems now plaguing the Northeast Corridor.

Some of the geographic similarities become apparent when maps of the two areas are drawn to the same scale and placed side-by-side as presented in Figure V-1. The two regions are about the same size and shape. The Northeast Corridor, as defined in other studies, encompasses about 57,000 square miles (55). The Texas Coastal Zone, as defined for this study, includes some 33,000 square miles. Furthermore, the distances between some major cities are equivalent, as shown in Table V-1.

Obviously, both regions contain extensive coastlines with bays and harbors serving numerous major seaports. The availability of water transportation has had a great effect on the location and growth of cities in both regions. The cities are major transportation hubs serving a large hinterland. This has resulted in a high level of industrial activities in the cities. Thus, the major developmental forces acting on both regions are very similar.

Contrary to popular belief, the Northeast Corridor is not just one huge city. In fact, less than 10% of the land area is urbanized. About 3% of the land area of the Texas Coastal Zone is urbanized. This means that about 90% of the land area in both regions is rural in nature. Agricultural activities are a major factor in the economy of both regions. More than 33% of the land area in the Northeast Corridor is still devoted to agricultural production. A whopping 83% of the Texas Coastal land is in farms and ranches (56).

FIGURE V-1 COMPARISON OF NORTHEAST CORRIDOR AND TEXAS COASTAL ZONE



Striking similarities exist between the Coastal Zone of Texas and the Northeast Corridor. The land areas are about the same; distances between major cities are similar; both regions have numerous seaports; and both areas are served by major elements of every mode of transportation. Although the Texas Coastal Zone may never contain 42 million persons, its population is growing enough to create some of the same transportation problems now evident in the Northeast Corridor.

TABLE V-1 EQUIVALENT DISTANCES BETWEEN CITIES

Texas Coastal Zone		Approximate Airline Miles		Northeast Corridor
Orange to McAllen	=	390	=	Boston to Washington
Houston to Corpus Christi	=	190	=	New York to Washington or New York to Boston
Houston to Beaumont	=	80	=	New York to Phildelphia
Houston to Texas City	=	35	=	Washington to Baltimore

Several city-pairs in the Northeast Corridor are the same distance apart as city-pairs in the Texas Coastal Zone. Thus the relative influence that one city has upon the other's future growth might be similar in both regions.

The population of the Texas Coastal Zone is expected to double in the next 30 years, increasing from 3 1/2 million in 1970 to 7 million by the year 2000 AD. The Northeast Corridor experienced a similar rate of growth when it was at the same stage of development. It's population increased from 3.6 million in 1820 to 7.2 million in 1850. Indeed the data presented in Table V-2 indicates that these two regions have very similar growth patterns except that the Texas Coastal Zone is about 150 years behind the Northeast Corridor in overall population growth. Considering the increased level of mobility of people today, the population of the Coastal Zone could grow at even faster rates.

Approximately 85% of the population of both regions live in urban areas. The cities of the Northeast Corridor are much older than Texas cities and have different urban forms. About half of the urban development in the northeastern region occurred before the automobile began to shape cities - about 1920. Consequently, the population density in the older portions of the cities is much higher than in the Texas Coastal Zone. However, the suburban development of the past twenty years looks very much the same in both regions.

Transportation systems serving both of these coastal regions includes major elements of every mode. Considerable rail, highway, and canal networks connect both regions and their extensive ports to large inland areas. Serving as transshipment points, their cities have become magnets attracting all types of industrial activity. Consequently, transportation is especially important to both regions in two ways. First, the transportation industry itself is an important sector of the

TABLE V-2 POPULATION GROWTH OF THE TWO REGIONS

Year	Population, Millions: Northeast Corridor	Population, Millions: Texas Coastal Zone
1800	2.2	-
1820	3.6	-
1850	7.2	0.05
1900	17	0.4
1920	24	0.7
1950	31	2.1
1970	42	3.5

Sources of Data: References 37 and 57

The population of the Texas Coastal Zone is expected to double in the next 30 years. The Northeast Corridor experienced a similar growth when it was at the same stage of development. These two regions exhibit similar growth patterns if the Texas Coastal Zone is assumed to be lagging the Northeast Corridor by 150 years.

economy; second, nearly all economic activity of both areas is heavily dependent upon transportation services.

Perhaps the most significant difference in the two regions, relative to transportation planning, is the difference in respective political jurisdictions. The Northeast Corridor spans all or parts of 10 states as well as the District of Columbia. The total are includes 119 counties. The Texas Coastal Zone, on the other hand, covers 36 counties all of which lie within a single state. Thus the opportunity for effectively planning and coordinating future developments in the Texas Coastal Zone is much better than it ever could have been in the Northeast Corridor.

The population of Texas Coastal Zone will probably never reach 42 million, but it will increase enough to create the potential for many of the same transportation problems that are now evident in the Northeast Corridor. A closer look at some of these transportation problems, and the types of developments in the Northeast Corridor, can yield information that can be used to avoid them in the Texas Coastal Zone.

URBAN FORM

Populations of the major metropolitan areas of both regions are listed in Table V-3. The population of the Houston Metropolitan area is expected to approach that of Washington, D.C., or Boston within the next 30 years. Thus, a comparison of these three cities is made in an effort to identify some of the alternatives and consequences of future developments in Houston.

This comparison is more concerned with the characteristics of the entire metropolitan development of these areas than with the development within their respective jurisdictional limits. The U. S. Census Bureau defines an "urbanized" area as one containing at least 50,000 persons in a continuous urban development of at least 1000 persons per square mile. Therefore, all comparisons made in this section are based upon urbanized area statistics.

Boston was founded in 1630 and soon established itself as one of the major seaports serving the American colonies. Many of the streets and travelways in use today were originally laid out to serve horse-drawn transportation. Fixed-way transit systems, installed in the 1880's, helped to shape the urban form. High density corridors radiate out from the city center along the major transit routes. Then, after the advent of the automobile and commuter trains, a low density perimeter developed around the older portions of the city. Thus, the urban form of Boston typifies the "High-Density Corridor" concept discussed in Section III (58).

Washington, D.C. was originally planned in 1791 as the nation's capital. The plan included broad thoroughfares radiating out from the center. A radial street pattern such as this would normally have stimulated high-density development at the center; however, building height restrictions kept the density levels in Washington, D.C. lower than was typical of other northeastern cities. The overall urban form of Washington, D.C. remained pretty much as dictated by the original plan until the Capital Beltway was opened during the mid-1960's. This circumferential freeway acted as a magnet pulling development outward so that now the entire development within the beltway is at a relatively constant density (59).

Although, Houston was founded in 1836, it did not really begin to grow until World War I, and its population has more than doubled since 1950. Thus almost all of the development in Houston was influenced by the automobile. Consequently it is characterized by relatively low density development in a circular shape with longer fingers extending outward along major highway corridors.

TABLE V-3 MAJOR METROPOLITAN AREAS OF BOTH REGIONS

Metropolitan Area	1970 Population
Northeast Corridor	
New York City-Newark	16,207,000
Philadelphia	4,022,000
Boston	2,653,000
Washington, D.C.	2,481,000
Baltimore	1,580,000
Providence-Pawtucket	795,000
Springfield-Chicopee	514,000
Hartford	465,000
Bridgeport	413,000
Wilmington	371,000
Texas Coastal Zone	
Houston	1,644,000
Beaumont-Port Arthur-Orange	280,000
Corpus Christi	213,000
Galveston-Texas City	152,000
McAllen-Edinburg	91,000
Brownsville	53,000

Source of Data: Reference 6

The population of the Houston Metropolitan Area is expected to approach three million in the next 30 years. Thus a comparison of its characteristics with those of Boston and Washington, D.C. might provide useful information concerning alternatives and consequencies of future developments.

Recent growth trends of these three metropolitan areas are compared in Figure V-2. The population of Boston has increased slightly during the past twenty years while the populations of the other two areas have increased rapidly. Houston now covers slightly more total land area than either of the other two cities even though its population is appreciably less. This is indicative of the lower overall population density of the Houston area.

The type of housing predominant in a city largely determines its overall population density; therefore, trends in population density and housing characteristics of these three urbanized areas are compared in Figure V-3. More than 70% of the residents of Houston live in single family housing and the resulting overall population density is only 2500 persons per square mile. Less than half of the people in Boston live in single family houses while slightly more than half of the residents of the Washington, D.C. area live in single family housing. Even so, the overall population density of Washington, D.C. is slightly greater than that of Boston. This is because Boston has a very high density central portion surrounded by large areas of low density suburbs while Washington, D.C. has a relatively constant medium density over most of its area.

The population densities of both Boston and Washington, D.C. are about double that of Houston. Perhaps the best way to visualize the differences in these cities is to imagine the changes necessary to make Houston look like the others. Houston would approach the urban form of Washington, D.C. if a city the size of Dallas could be stacked on top of the existing development. The changes needed to make it approach the urban form of Boston are even more drastic. An additional million persons would have to be added to several corridors extending from downtown outward to Loop IH 610.

Another interesting factor is indicated in Figure V-3. Since the mid 1930's, partially because of low interest loans sponsored by federal programs, there has been a nationwide trend toward single family housing units. Apparently this trend reversed between 1960 and 1970. The increase in apartment dwellers may have been caused by any or all of the following factors:

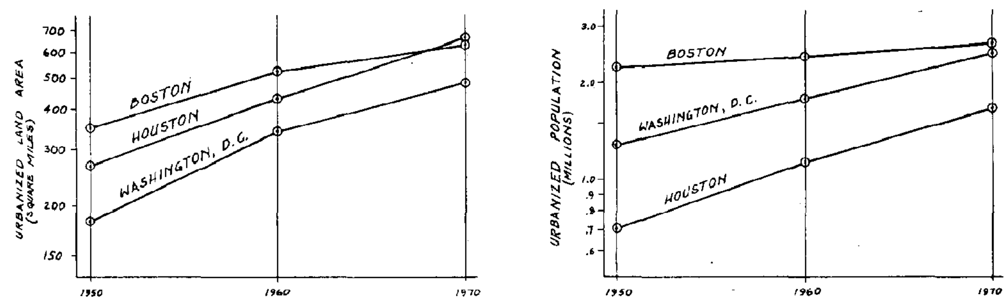
(1) Economic conditions - high interest rates and tight money;

(2) Baby boom of 1940's - large increase in number of new families being formed;

(3) Apartment design - more amenities included in modern apartments; or

(4) Change in preferences - an increasing number of families in the age group for which apartment living is attractive.

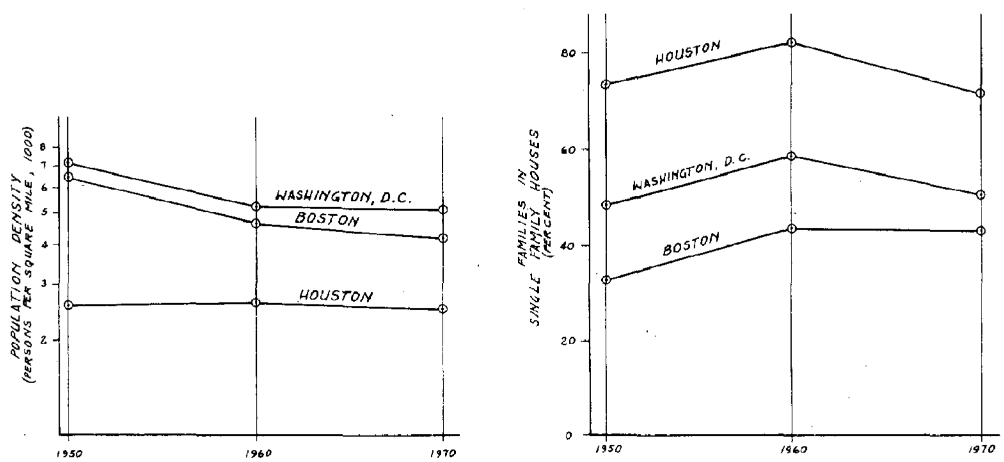
FIGURE V-2 GROWTH TRENDS OF THREE URBANIZED AREAS



Source of Data: Reference 60

Houston has grown rapidly in population and land area over the past 20 years. It covers more land area than either Boston or Washington, D.C. even though its population is less. This is indicative of the lower overall population density of the Houston area.

FIGURE V-3 POPULATION DENSITY AND HOUSING CHARACTERISTICS



Source of Data: Reference 61

The predominant type of housing in a city largely determines its population density. Fewer persons live in single family houses in the northeastern cities; consequently, their population densities are about double that of Houston. However, it appears that the long-term trend towards single family housing may have reversed between 1960 and 1970.

Whatever the cause, this new trend has significant implications for future plans. If 30% of the future residents of Houston are willing to live in apartments, high density areas can be developed which can be economically served by transit systems.

TRANSPORTATION SYSTEMS

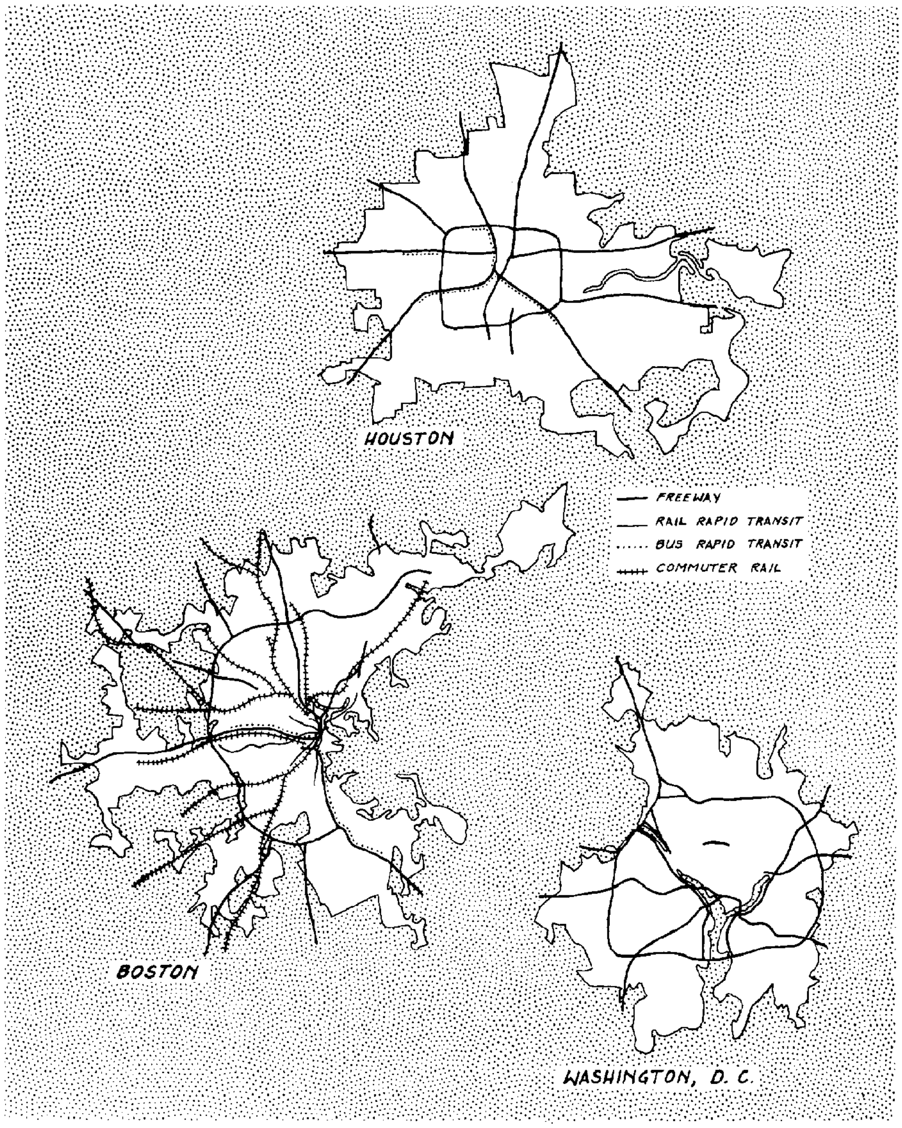
Urban transportation systems help to shape new development in a city; conversely, the established urban form constrains the types of urban transportation that can be used effectively within a city. Houston, Boston, and Washington, D.C. provide an interesting contrast in urban forms and transportation systems. Their respective urbanized areas and major transportation elements are compared in Figure V-4.

Houston and Washington, D.C. presently depend entirely on automobiles and buses operating on streets and freeways. Boston's urban transportation system, on the other hand, includes almost every existing mode of urban transportation. Boston still uses some of the trolley and street car lines that were originally built in the 1880's. Boston built the nation's first subway system in 1897 and connected it to some elevated lines to form a rail rapid transit system having six major routes that are still in use today. It is also served by ten commuter rail lines and a large bus operation. Even with all of these transit facilities, Boston has more miles of freeway than either Houston or Washington, D.C. (See Table V-4).

The automobile is the backbone of the urban transportation system in all three cities. Data taken in the 1960 census, presented in Figure V-5, indicate that even then more than two-thirds of the work trips were made by automobile. Unfortunately, similar data were not taken in the 1970 census, but automobile ownership has increased in all three areas in the past ten years so it is safe to assume that an even higher percentage of work trips are made by automobile today. The bulk of transit ridership in these cities is in work trips; therefore, the percentage of urban travel made by the automobile is certainly much greater than indicated by work trips alone.

Another interesting factor is indicated by a comparison of the automobile ownership and work trip characteristics. The percentage of workers using transit for work trips in each city is almost identical to the percentage of families that do not own a car. Numerous transit studies recently conducted in various cities in Texas have revealed that, without exception, more than half of the bus riders are from families that do not own a car. Furthermore, 85% to 90% of the bus passengers stated that they did not have a car available for that particular trip. Apparently then, potential transit riders are largely limited to those families that do not own cars and some of the one-car families.

FIGURE V-4 COMPARISON OF THREE URBANIZED AREAS



Sources: References 62 and 63

These three cities provide an interesting contrast in urban forms and urban transportation systems. All three cities cover about the same land area, but their urban forms are quite different. Houston has relatively constant low density developments, Washington, D.C. has constant medium densities, and Boston has a very high density core surrounded by low density suburbs.

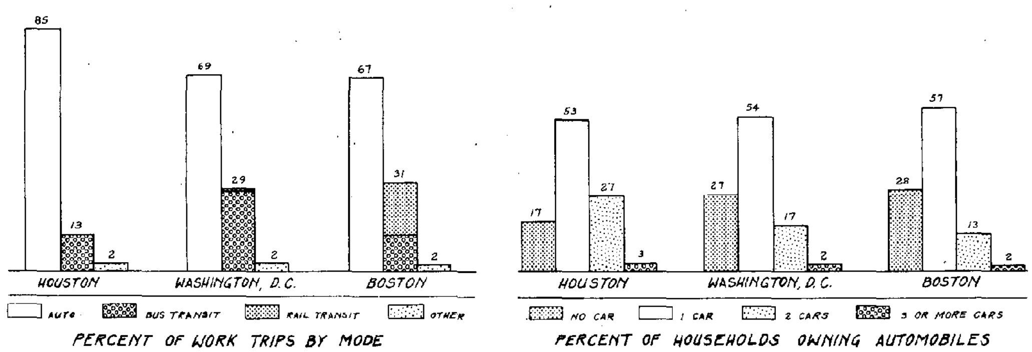
TABLE V-4 URBAN TRANSPORTATION SYSTEMS

Characteristic	Boston	Houston	Washington, D.C.
1970 Population, millions	2.7	1.6	2.5
1970 Land Area, sq. miles	630	660	480
Freeway, miles	189	163	164
Rail Rapid Transit, miles	42	0	0
Trolley & Streetcar, miles	34	0	0
Commuter Rail, miles	160	0	0
Number of City Buses	∿1200	334	1778
Number of Rail Vehicles	∿ 900	0	0

Sources of Data: References 15, 58, 62, and 63

Houston and Washington, D.C. presently depend entirely upon automobiles and buses for the movement of people within the urban area. Boston, on the other hand, has extensive rail systems in addition to automobiles and buses. Yet Boston seems to have greater problems with urban transportation than the other cities.

FIGURE V-5 TRANSIT RIDERSHIP AND AUTO OWNERSHIP



Source of Data: Reference 54

These data from the 1960 census indicate that transit riders come primarily from families with no car. Both Washington, D.C. and Boston have about the same total ridership, but Boston's is split between several modes. The Boston transit system has experienced severe operating deficits while the one in Washington, D.C. seems to be thriving.

Washington, D.C. seems to be the only one of the three cities with a thriving transit operation. It has the highest level of transit ridership of any city its same size in the nation. Indeed, Washington, D.C. has actually experienced increases in transit ridership during recent years while other cities were experiencing a steady decline in ridership. Several factors seem to contribute to the relative success of Washington's four privately owned bus companies. First, the medium-high density development over a large area provides a type of development that is well suited for bus operations. Second, an unusually large number of persons are employed within an area having limited parking and relatively high parking fees (65).

Transit operations in Boston, on the other hand, are encountering severe problems with decreasing ridership and rapidly increasing operating costs. The Massachusetts Bay Transportation Authority (MBTA) operates almost 1600 of the more than 2100 transit vehicles serving the Boston area. MBTA has been incurring increasingly large operating deficits in recent years. Its total operating deficit for 1971 is estimated to be $75 million - this is a total of $30 per person in the Boston Metropolitan Area (66) (67).

Boston and Washington are both serving about the same total number of transit riders; however, Boston is splitting their ridership between several modes while Washington uses only buses. Indeed, several of the major high density corridors in Boston are served by rail rapid transit, commuter rail, and buses using freeways. Thus the different modes are competing directly for the same riders. This factor may explain some of the financial difficulties of Boston's transit system.

Washington, D.C. is currently building a rail rapid transit system with 98 miles of routes at an estimated cost of more than $3 billion. A small portion of this rail rapid transit system is expected to open in 1976 and the remainder should be operational by 1980. It will be interesting to see if this new transit system attracts new riders or if it just diverts passengers from existing bus operations.

A new rail rapid system was approved in November 1962 and is now nearing completion in San Francisco, and one has recently been approved for Atlanta. The least expensive of these three new rail rapid transit systems is estimated to cost more than $1.5 billion dollars. The magnitude of such costs is more apparent when they are compared to the costs of other urban transportation systems. For instance, the total cost of replacing the entire bus system in Washington, D.C. is estimated to be less than $90 million. The total investment in the 516 miles of highways and freeways in Harris County, Texas, to use an example from the Coastal Zone, is less than $600 million (See Table V-5).

TABLE V-5 COST COMPARISON OF VARIOUS URBAN TRANSPORTATION SYSTEMS

System	Cost
1. Washington, D.C.'s Rail Rapid Transit System 98 route miles	$3,000,000,000
2. Washington, D.C.'s Bus Transit System Estimated replacement cost of 1780 Buses, garages, shops, and equipment	$90,000,000
3. Harris County Highway System, Total investment from 1917 to 1970 in 516 miles of highways and freeways	$594,000,000

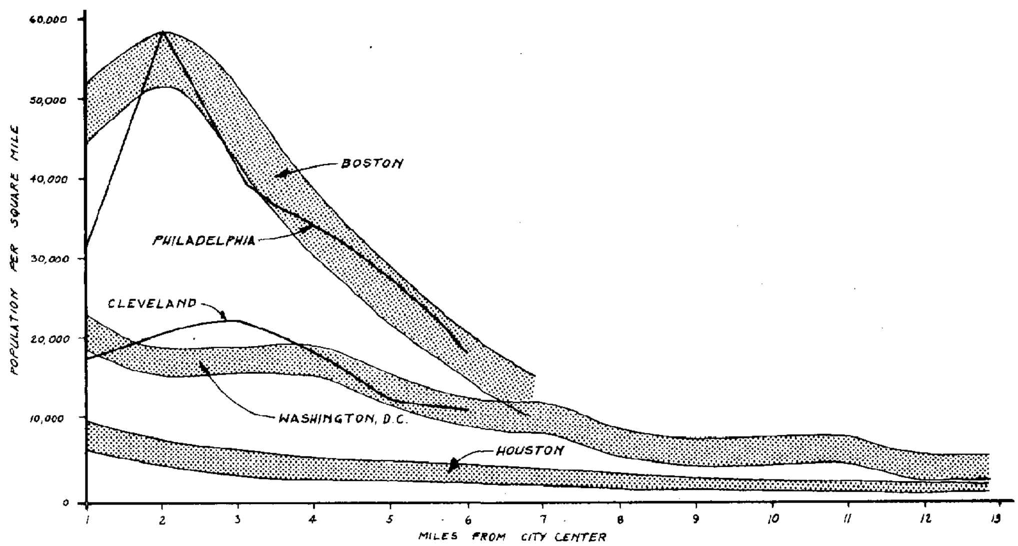
Sources of Data: References 68, 69, and 70

New rail rapid transit systems are being built in San Francisco and Washington, D.C., and one has recently been approved for Atlanta. The least expensive of these systems will cost more than $1.5 billion. Such astronomical cost figures have little meaning until they are compared with the costs of other urban transportation systems.

Most experts agree that high density corridors are needed to support a rail rapid transit system such as those presently operating in Boston, Philadelphia, and Cleveland. The relative densities of corridors in these three cities as well as Washington, D.C. and Houston are compared in Figure V-6. Boston and Philadelphia both have extremely high-density corridors while Cleveland is more like Washington, D.C.. If corridor density were the only consideration, these cities should be well suited for rail rapid transit service, yet, their transit systems are all experiencing severe financial difficulties. These factors should be included in the evaluation of future transit plans for Houston.

Transit service in Houston is provided by a privately owned bus company operating less than 350 vehicles. Despite decreasing ridership in recent years, the bus company has managed to maintain a financially sound operation. However, there are strong indications that this situation will not continue for much longer; consequently a large transit study is now being conducted to determine future transit alternatives for Houston. Two factors contribute largely to the unfavorable transit conditions in Houston. The population density is less than needed to support an economical bus operation and the automobile ownership and usage is higher than in the other two cities.

FIGURE V-6 COMPARISON OF CORRIDOR DENSITIES



Source of Data: Reference 60

Most experts agree that high density corridors are needed to support a rail rapid transit system such as those operating in Boston, Philadelphia and Cleveland. These cities all have high density corridors and yet their transit systems are experiencing severe financial difficulties. These factors should be considered in evaluating future transit plans for Houston.

Recent increases in the percentage of families living in multi-family dwelling units indicate that substantial areas of higher density development will occur within the Texas Coastal Zone in the future. These areas might be effectively served by bus rapid transit if appropriate steps are taken to locate and orient this higher density development rather than to have it occur randomly. Future transportation problems will largely depend upon how well the cities take advantage of the opportunity to shape this higher density development for positive results. The following factors should be considered by the cities in developing a workable policy relative to achieving a balance between land use and transportation:

(1) Many Coastal Zone residents have demonstrated a willingness to live in medium-density developments (garden apartments), but their willingness to live in high-density developments (high-rise apartment buildings) is not known;

(2) Numerous areas are suitable for medium-density development while few corridors are available for high density development within the existing built-up area;

(3) Bus transit operations and medium density developments are more nearly compatible with existing automobile-oriented development;

(4) Bus transit systems have been demonstrated to be operationally and financially successful when serving medium-density areas; and

(5) An extensive street and freeway system is already in existance.

GOODS MOVEMENT

Both the Texas Coastal Zone and the Northeast Corridor are served by major elements of every mode of intercity goods movement, and their economic activities are heavily dependent upon these transportation services. Perhaps this is best indicated by the data presented in Table V-6 concerning the volume of goods shipped from major production areas in each region. These data are from the 1967 Census of Transportation which lists one production area in the Texas Coastal Zone (includes the Houston-Galveston and Beaumont-Port Arthur-Orange Metropolitan Areas) and 8 production areas in the Northeast Corridor. Unfortunately, these data do not include shipments made by pipelines.

It is surprising to note that the one production area in the Texas Coastal Zone shipped more tons of goods than all 8 production areas in the Northeast Corridor. The modal distribution of shipments indicates that there is a heavier reliance on water transportation in the Coastal Zone than in the Northeast Corridor. However, it should be noted that these data are for shipment from the production area to other production areas and other portions of the nation. Hence, many of the shipments in the Northeast Corridor were between production areas in the same region - movements for which trucking is well suited.

A comparison of the commodity distribution of these shipments indicates a more diversified economy in the Northeast Corridor. The bulk of the Texas shipments were petroleum products. Indeed much of this petroleum was destined for the Northeast Corridor.

Water transportation is extremely important to both regions. There are 23 major ports in the Northeast Corridor and 13 major ports in the Texas Coastal Zone. Relative port activities of the two regions during 1969 are compared in Table V-7. Texas ports shipped more tons of goods, but total port activity was greater in the Northeast Corridor.

These data indicate a basic difference in the goods movement picture for the two areas. The Northeast Corridor consumes more tons of goods than it ships due to its high concentration of population. Thus a continuous flow of goods into the region is essential for the survival of its residents. If only one mode of transportation suffered a long breakdown, many essential items would be in short supply in just a few days. As the population of the Texas Coastal Zone increases, this same situation will tend to develop.

TABLE V-6 SHIPMENTS FROM PRODUCTION AREAS

Description	Texas Coastal Zone (1 Production Area) Tons (1000's)	Texas Coastal Zone (1 Production Area) % Of Total	Northeast Corridor (8 Production Areas) Tons (1000's)	Northeast Corridor (8 Production Areas) % Of Total
Total Shipments	157,071	100	129,816	100
Modal Distribution				
Rail	10,053	6.4	22,456	17.3
Truck	6,911	4.4	74,116	57.1
Air	-	-	111	0.1
Water	140,107	89.2	32,196	24.8
Other	-	-	937	0.7
Commodity Distribution				
Petroleum & Coal	136,996	87.4	28,343	21.8
Chemicals	14,678	9.4	18,084	13.9
Food	1,746	1.1	18,128	14.0
Primary Metals	1,571	1.0	8,679	6.7
Fabricated Metals	969	0.6	4,843	3.7
Stone, Clay, etc.	567	0.4	8,139	6.3
Machinery	126	0.1	937	.7
Pulp, Paper, etc.	-	-	6,049	4.7

Source: Reference 35

Both the Texas Coastal Zone and the Northeast Corridor are major shipping areas; in fact, the total tons of goods shipped from the Coastal Zone actually exceeds that of the Northeast Corridor. Thus the economic activities of both areas is heavily dependent upon transportation services.

TABLE V-7 PORT ACTIVITY IN 1969

Category	Texas Coastal Zone (13 Ports) Tons (1000's)	Texas Coastal Zone (13 Ports) % Of Total	Northeast Corridor (23 Ports) Tons (1000's)	Northeast Corridor (23 Ports) % Of Total
Total Activity	175,606	100	405,517	100
Receipts	62,767	35.7	261,931	64.6
Shipments	108,554	61.8	86,723	21.4
Local Movement	4,285	2.5	56,863	14.0

Source: Reference 38

Water transportation is extremely important to both the Texas Coastal Zone and the Northeast Corridor. These data indicate one of the basic differences in the goods movement in the two regions. The Northeast Corridor consumes more goods than it produces due to its large concentration of population. As the population of the Coastal Zone increases, this same situation will tend to develop.

INTERCITY TRAVEL

Between 1950 and the mid-1960's, substantial improvements were made in intercity travel conditions in both the Northeast Corridor and the Texas Coastal Zone. Construction of new highways, especially the Interstate system, and improvements in automobiles resulted in a 30% to 40% reduction in driving times between major cities. The introduction of jet aircraft decreased flying time by a similar percentage. The advent of relatively light-weight diesel-powered passenger trains shortly after WW II also resulted in improvements in intercity rail passenger service. However, these trends toward reduced intercity travel times have already reversed in the Northeast Corridor and they appear to be bottoming out in the Texas Coastal Zone (20)(71)(72).

Cities within the Northeast Corridor generate large volumes of intercity traffic. This is primarily due to their size and secondarily due to their related economic activities. Intercity highway facilities within these heavily traveled corridors have been appreciably better than in directions perpendicular to the corridors. Thus the transportation facilities themselves stimulated growth along the corridor - small communities developed into large communities with economies largely dependent upon the major urban centers. These new urban developments generated more traffic along the corridor requiring more facilities which in turn stimulated more growth in a seemingly never ending cycle. Considering the long lead times between design and construction of major highway facilities today, it appears that intercity travel times in the Northeast Corridor will continue to increase during the foreseeable future.

Intercity traffic also causes urban transportation problems in those cities located in a corridor between major metropolitan centers. In Baltimore, for instance, about 24% of all external highway trips are through movements. This is considerably larger than the 3% to 5% that is typical for cities of the same size (72).

Aircraft and terminal delays at Northeast Corridor airports increased more than 20% between 1968 and 1969. These delays declined somewhat during 1970, but the long term trend indicates that aircraft delays will increase in the future. These delays, combined with increasing congestion on airport access roads, have drastically reduced the attractiveness of air travel between cities within the Northeast Corridor (20).

In an effort to counteract the deterioration in intercity travel along the corridor, a new high-speed rail passenger service was inaugurated in January 1969. The Metroliner, using new equipment and improved roadbed, achieved a one-hour reduction in travel time between New York City and Washington, D.C.. However, the Metroliner equipment cannot achieve its full potential on existing roadbeds due to numerous curves and grade crossings. Nevertheless, this form of intercity travel has diverted many passengers from airplanes and automobiles.

The Texas Coastal Zone has not experienced such severe problems in intercity travel; however, the long term trend toward improvement has bottomed out. Overall intercity travel conditions within the zone are probably better now than they will be at any time in the foreseeable future. As its population increases, the Texas Coastal Zone will begin to experience many of the same problems as the Northeast Corridor.

It is interesting to note that the distance from Houston to Corpus Christi is the same as from New York City to Washington, D.C.. In fact, the distances from Houston to San Antonio and Houston to Dallas are also similar. Existing traffic along these corridors are not yet approaching volumes sufficiently high to support a high speed train service like the Metroliner. Eventually, however, these city-pairs may need such a service so future plans should consider this possibility.

The Texas Coastal Zone is in a far better position to plan for future problems than the Northeast Corridor. All of the Coastal Zone lies within Texas while the Northeast Corridor stretches across 10 states and the District of Columbia. Hence, Texas has an opportunity to apply any lessons that can be learned from the history of the Northeast Corridor.

Probably the most important lesson is the need to recognize the permanency of travel corridors. Both intercity and urban transportation facilities represent a permanent commitment to the movement of persons and goods between areas of major activities. The need for transportation services will continue even though the facilities may change drastically. Thus, a major transportation facility should be considered as a permanent commitment to transportation - not just a highway or railroad. Wherever possible, sufficient right-of-way should be acquired to provide future flexibility for the corridor. This will enable the Texas Coastal Zone to better meet the transportation needs of the future.

FUTURE ALTERNATIVES

SUPER-DRAFT PORT

INDUSTRIAL GROWTH

Water-borne transportation in Texas is closely related to industrial activities in the Coastal Zone. This relationship is reflected in the commodity distribution of goods carried by water. Texas ports handle a total of almost 200 million tons of goods each year. About three-fourths of this tonnage is liquid bulk cargo going to or from the petro-chemical industry concentrated in the Coastal Zone. Another sizeable segment is dry bulk cargo (aluminum ore, sulfur, grain, etc.) serving the primary metals industry, mining industry, and agricultural industry of Texas. An effective water transportation system is essential for the continued growth of these industries (38).

The Texas Coastal Zone contains almost half of the nation's petrochemical industry and about one-fourth of its refining capability. Ocean-going vessels operating out of Texas ports carry about 80 million tons of liquid petro-chemical products annually. About 25 million tons of this is crude petroleum being exported from Texas to be refined elsewhere. If the refining activities grow as projected during the next 15 years, this outward flow of crude oil will be reversed so that Texas is importing more crude oil than it is now exporting. Thus, the petrochemical industry is intensely concerned about the size of tanker ships that can be served at Texas ports.

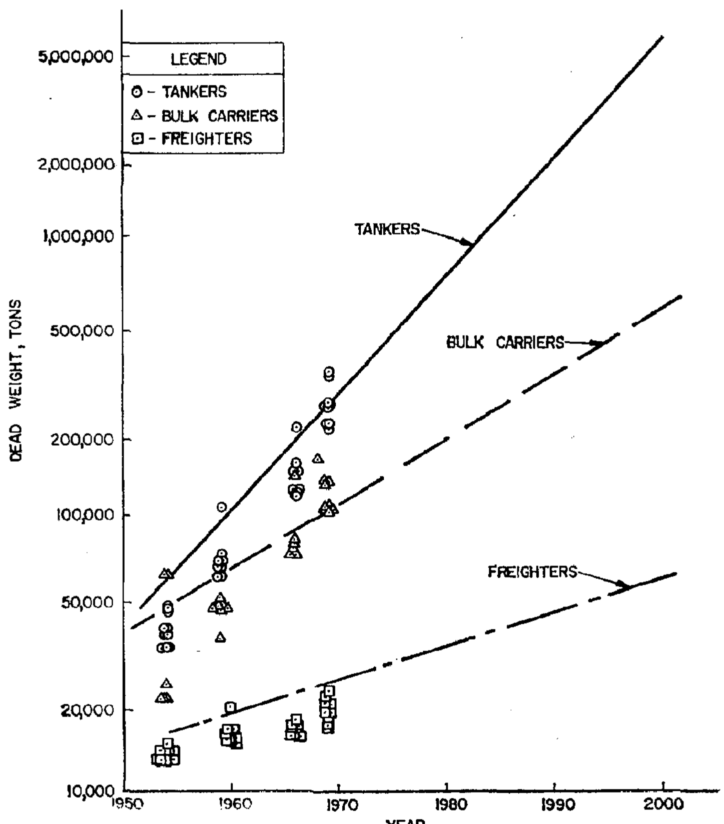
The aluminum industry in Texas has been growing rapidly in recent years and is expected to grow faster in the future. Texas is presently importing about 8 million tons of bauxite from South America each year. This tonnage could easily double or triple in the next twenty years if the aluminum industry continues to grow. Hence, the aluminum industry as well as the mining industry and the agricultural industry in Texas will probably stimulate rapid increases in the amount of dry-bulk cargo being handled by ocean-goind carriers in the future.

TRENDS IN SHIP SIZES

Maximum ship sizes, especially tankers and bulk-carriers, have been increasing at an astounding rate during the last 30 years. In fact, the trend has been for the largest tankers to double in size every seven years and for bulk carriers to double in size every fifteen years. If these trends continue until 1985, the maximum tanker size will exceed one million dead-weight tons, and the maximum bulk carrier will be at least 3000,000 dead-weight tons (See Figure VI-1). Of course, trends in maximum ship size can be somewhat misleading since many ships being built each year are much smaller than these giants. However, the "average" size of ships under construction has also been increasing rapidly (Refer to Figure IV-8, page IV-12) during recent years.

Such rapid increases in ship sizes are a result of economic considerations in ocean transport. The cost of labor and the investment in each vessel has increased drastically during recent years so ship companies are seeking ways to increase the annual payload of each vessel. The total amount of cargo carried each year can be doubled by either doubling the vessel size or doubling its speed. Horsepower

FIGURE VI-1 TRENDS IN MAXIMUM SHIP SIZES



Source: Reference 73

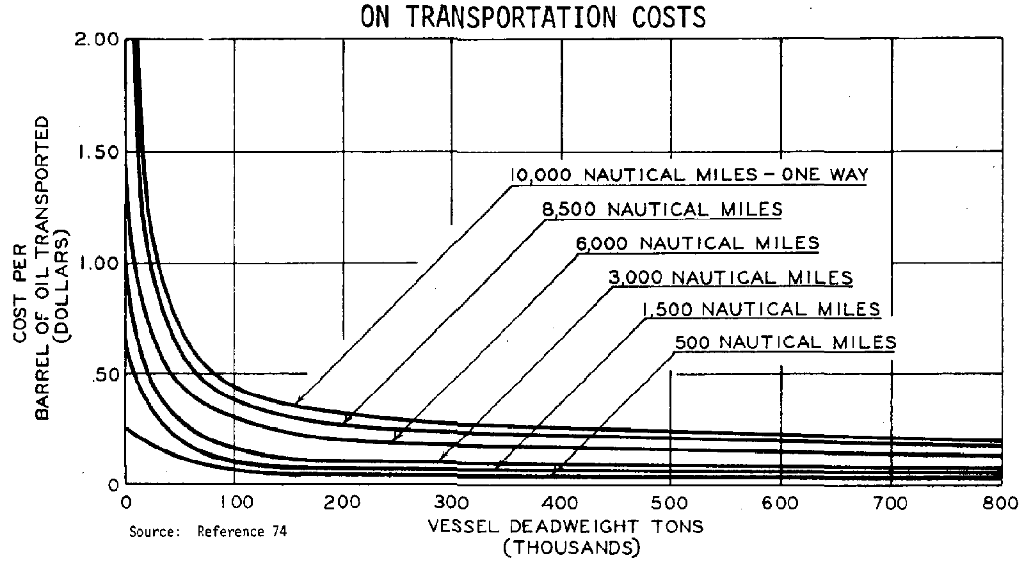
Maximum ship sizes have been increasing at an astounding rate during the past thirty years. If these trends continue until 1985, tankers exceeding 1,000,000 tons and bulk-carriers exceeding 300,000 tons will be built.

requirements increase as the square-root of tonnage or as the 2.7 power of speed. In other words, if the size of the ship is doubled, the horsepower must be increased by a factor of 1.42 to be able to achieve the same speed. On the other hand, if the speed of a ship is to be doubled, the horsepower must be increased by a factor of 6.5. Thus, the trend has been toward larger ship sizes.

The influences of vessel size and route length on the cost of transporting liquid products are indicated by the curves in Figure VI-2. The calculations for these curves were done about five years ago when it was thought that construction costs would increase sharply for vessels over 200,000 deadweight tons. This sharp increase has not occurred yet, and vessels approaching 500,000 deadweight tons are now being built. Consequently, these curves may flatten out too quickly with increasing vessel size but they are still indicative of the trends.

The economical size of vessels needed to import crude oil to Texas refineries will depend upon the source of the crude. If it is brought in from South America, or other ports in the Atlantic, vessels of 250,000 deadweight tons should be sufficiently large to achieve economical operations. However, the crude oil is to be imported from the Middle-East or even from Alaska, the largest vessels available will probably be used. Existing channel depths at Texas ports are inadequate to handle either size ship.

FIGURE VI-2 INFLUENCES OF VESSEL SIZE AND ROUTE LENGTH ON TRANSPORTATION COSTS



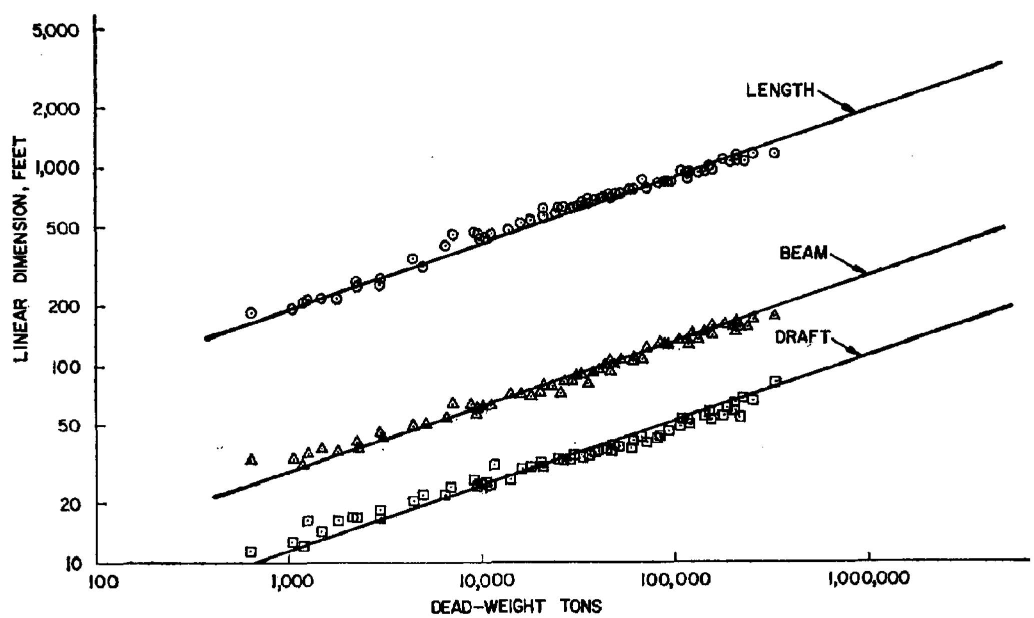
Source: Reference 74

Lower transportation costs are achieved by using larger vessel sizes. The minimum economical size for tankers used to import crude oil to Texas in the future will be at least 250,000 deadweight tons.

The sizes of ships have increased drastically since the transition from sailing vessels to powered vessels. Nevertheless, ship builders have maintained relatively constant aspect ratios in the design of all powered ships regardless of size. As long as aspect ratios are held constant, the key dimensions (length, beam, and draft) of a ship must vary as the cube-root of the tonnage.

The information presented in Figure VI-3 verifies this relationship between dimensions and tons. The straight lines define a cube-root relationship. The data points are for representative ships of all types constructed during the last fifteen years. The data points follow the curves closely over a very broad range of tonnage (from 600 tons to 320,000 tons). Thus, the probable draft of future ships can be predicted from this curve. Calculated drafts of fully-loaded ships of different sizes are listed in Table VI-1. The maximum depth of Texas ports is now 40 feet. If minimum economical sizes of tankers and bulk carriers are to be served in the future, much deeper port facilities will be required.

FIGURE VI-3 SHIP DESIGN CHARACTERISTICS



Source: Reference 73

As long as the aspect ratios of ships are held constant, the linear dimensions will vary as the cube-root of tonnage. Data for representative ships of all types constructed during the last fifteen years follow the cube-root relationship over a broad range of tonnage.

TABLE VI-1 CALCULATED DRAFTS OF FULLY LOADED SHIPS

Ship Size, Deadweight Tons	Draft, Feet
50,000	40
100,000	51
250,000	69
500,000	87
1,000,000	110
5,000,000	188

The maximum depth of Texas ports today is only 40 feet. If economical sizes of tankers and bulk carriers of the future are to be served, much deeper port facilities will be required.

ALTERNATIVES AND CONSEQUENCIES

Texas can pursue several alternative courses of actions relative to future needs of the ocean-going segment of the total transportation system. Each alternative course has certain probable consequencies associated with it. Several alternatives and the probable consequencies of each are discussed in the following paragraphs.

Of course, one alternative course of action that must be considered is to do nothing about the depth of port facilities along the Texas coast. Future growth of the Texas economy will probably suffer if this alternative is followed. The existing channel depths are already inadequate to serve modern tankers and bulk-carriers that are large enough for economical speration. Thus, the cost of ocean transport to Texas is higher than to locations with deeper port facilities. This may be one of the reasons that ocean traffic at Texas ports has not increased in the last ten years. Nevertheless, higher ocean transportation costs will probably discourage future expansion of the petroleum refining, primary metals, and other sectors of the economy which tend to utilize ocean transport.

Existing channels at some of the ports might be deepened to handle larger ships. If, for instance, channel depths were increased to 75 feet, ships up to 250,000 tons in size (tankers and bulk carriers) could enter the ports. This would permit economical transport between

Texas and most ports on the Atlantic. However, these channels would extend several miles out into the Gulf, and they would be expensive to maintain. Some of the existing ship channels are already experiencing traffic congestion which would be further increased in the future under this alternative. This alternative would tend to stimulate future growth around those ports with deeper channels.

Several off-shore terminals might be constructed at various locations along the Texas coast. These terminals would be connected to the land-side facilities with large diameter pipelines. Each terminal would probably be designed to service one or two ships at a time. These terminals could be located far enough out in the Gulf to attain depths sufficient to serve vessels of sufficient size to economically travel from anywhere in the world. Solid bulk materials could also be handled through pipelines to off-shore terminals if slurry processes are used. Terminals designed to serve solid bulk-carriers might not be located as far off-shore as liquid bulk terminals. However, port operations might be interrupted by heavy seas in the open Gulf. Under this approach, land-side facilities could be located wherever needed, and future growth would tend to develop all along the coast.

One other concept that has been proposed is the construction of a single all-purpose Super-Port somewhere off the Texas coast. This facility might be constructed on a floating platform or an artificial island where natural water depths are more than 100 feet. It would be designed to serve numerous ships of all types. The corresponding land-side facilities could be dispersed to some extent by running pipelines to different location. Nevertheless, a single port would tend to concentrate all future growth related to ocean-traffic in one general location along the coast.

Each of these alternatives will have some impact on other forms of transportation within the Texas Coastal Zone. They will also have slightly different effects on future industrial activities in the area. Considering the relative importance of ocean transport to the future of Texas, it seems imperative that further studies be conducted concerning the various alternatives before one is selected.

CURRENT PROBLEMS

The section of the Gulf Intracoastal Canal in Louisiana connects Texas ports to an extensive inland waterway system that covers the mid-section of the United States (See Figure VI-4) The volume of inland waterway traffic crossing the Texas-Louisiana border had been increasing at a rapid rate, doubling every ten years, until it reached about 33 million tons in 1967. In the next three years it increased slightly to a total of 36 million tons in 1970. This leveling off in traffic growth may be largely due to problems on the Louisiana portion of the waterway system.

All of the Texas portion of the canal are essentially at sea-level so no locks are required to change water elevation. However, a portion of the canal in Louisiana is some distance inland and has several locks along its length. These locks are currently acting as bottle-necks constraining the flow of waterway traffic. Barges sometimes have to wait for 24 to 30 hours to gain passage through the locks. These delays at locks can more than double the normal travel time from Texas to the Mississippi River. The channel dimensions in this segment of the canal are 16' deep by 200' wide, but the dimensions of locks on the main canal are less commodious (See Table VI-2).

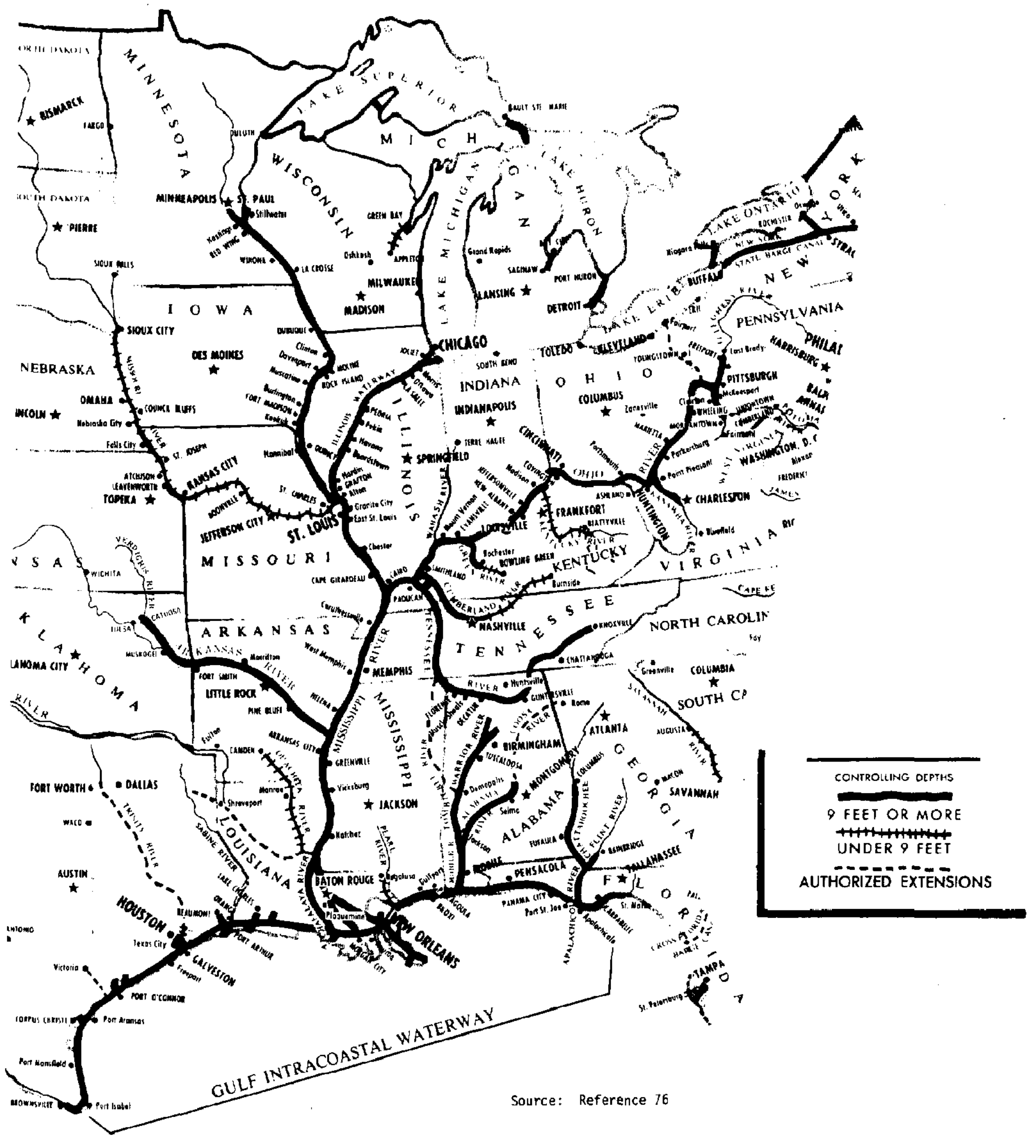
TABLE VI-2 DIMENSIONS OF LOCKS ON GULF INTRACOASTAL WATERWAY

Lock	Dimensions
Calcasieu	75' by 1180'
Vermilion	56' by 1182'
Old River	75' by 1200'
Port Allen	84' by 1200'
Bayou Boeuf	75' by 1160'

Source: Reference 75

Locks on the Louisiana segment of the Gulf Intracoastal Waterway are severe bottlenecks. Barges sometimes have to wait 24 to 30 hours to gain passage. These delays can more than double the normal travel time from Texas to the Mississippi River.

FIGURE VI-4 CENTRAL PORTION OF INLAND WATERWAY SYSTEM



Source: Reference 76

The Gulf Intracoastal Waterway connects Texas ports to the extensive central portion of the nation's inland waterway system. Texas traffic must travel through the congested Louisiana segment in order to reach the Mississippi River.

A total of 65 million tons of cargo traveled the Louisiana segment of the waterway. Some of this traffic was local in nature, but 36 million tons of it was traveling to or from Texas. Essentially all of the Texas traffic must pass through the Calcasieu and Vermilion locks as well as others. Vermilion lock is the smallest lock; therefore, it is the most constraining element of the system. The calculated ultimate traffic capacity of this lock, based upon the assumptions listed in Table VI-3, is only 70 million tons per year if it operates 24 hours a day, 365 days a year. Thus, Texas traffic consumes at least half of the total ultimate capacity of this lock.

TABLE VI-3 CALCULATION OF ULTIMATE CAPACITY OF VERMILION LOCK

Assumptions:

- Maximum Flotilla Size

  5 barges, 1000 tons each, (26' x 175')

  1 tow-boat (25' x 80')

  Total Size: 26' x 955'
- Average Lockage Time - 30 minutes
- 20% of Barges are empty
  (due to imbalance of traffic)
- Flotillas are waiting to enter lock after each operation

Calculations:

- Hourly capacity is

  5 x 1000 x 2 = 10,000 tons/hr.
- But 20% of barges are empty, so

  Effective Hourly capacity = 8,000 tons/hour
- If operation is continuous,

  8000 x 24 x 365 = 70,080,000 tons/year

A total of 65 million tons of goods traveled the Louisiana segment of the canal in 1970. Some of this traffic was local in nature, but 36 million tons of it was traveling to or from Texas. Thus, Texas traffic consumes at least half of the total capacity of this lock.

The segment of canal through Louisiana is outside of the geographical boundaries of Texas, but it is certainly a part of the inland waterway system in Texas. Traffic congestion on this segment is already deterring continued growth in Texas waterway traffic. Most of the growth in water-oriented industrial activities during the last 15 years has been associated with the waterway. More than 4 out of every 5 tons of additional water traffic during this time has been on the waterway. If Texas industry is to continue to grow, some provision must be made to handle the resulting increase in demand for transportation.

Actually, the situation is even worse than these calculations indicate. The calculations were based upon an assumption that only maximum size flotillas (5 barges plus tow-boat) use the lock. However, data concerning traffic using various segments of the canal reveal that the average flotilla crossing the Texas-Louisiana border contained only two barges. Thus, this lock has very little capacity remaining under present operating conditions.

ALTERNATIVES AND CONSEQUENCIES

No Waterway Improvement. If there is no improvement in this section of the waterway, it will not be able to accommodate much additional traffic. The net result will probably be a gradual relocation of waterway-related industry away from the Texas Coastal Zone. However, there are other modes of transportation that might be used to carry goods around this bottleneck.

Most of the traffic traveling between Texas and other points on the inland waterways is liquid bulk (petroleum crude or products) which could feasibly be shipped by pipeline. Current pipeline capacity in the corridor between Texas and Louisiana is sufficient to transport about 50 million tons per year. This capacity would need to be almost doubled in order to serve the projected increase in demand during the next ten years. The additional pipeline capacity at the Texas border would be equivalent to a 48" diameter pipe.

Three main-line railroads connect the Texas Coastal Zone to the Mississippi River near New Orleans. Existing traffic in this rail corridor is less than 20% of its current capacity. Therefore, the existing rail facilities have sufficient capacity to accommodate all of the projected increase in traffic during the next ten years. However, shipments of petroleum products on railroads have declined sharply in recent years - partly because of economic considerations and partly because of the hazards involved.

Of course, the projected increase in demand for goods movement could be handled by carrying the goods in ocean vessels between Texas ports and the Port of New Orleans and then using barges to take them to their final destination. However, this procedure would entail additional handling which would result in higher transportation costs. Also, this would compound existing traffic congestion problems in some ship channels.

Improved Locks. The existing capacity of locks along this section of the waterway could be doubled by enlarging and modernizing them. Such a course of action would probably encounter few problems of an environmental nature. Thus, the improvements could probably be completed in 5 or 6 years with expeditious processing. However, the locks would still be the constraining elements to the flow of traffic along the waterway. Even if their capacities were doubled, the projected increase in traffic is such that within ten years the congestion would probably be as severe as it is today.

New Constant-Level Waterway. The ultimate capacity of an open canal 16' deep by 150' wide, such as between Galveston and Sabine Lake, is at least five times as great as the capacity of the existing locks. Therefore, the construction of a new constant-level waterway facility through Louisiana would provide a greater capacity than could ever be obtained at the locks. If such a facility were built, much of the traffic traveling to or from Texas would be able to reach its destinations without having to pass through a lock. Hence, future growth in traffic would be relatively unconstrained. However, such a major construction project probably could not be approved and completed in less than 20 years.

COASTAL HIGHWAYS

BACKGROUND INFORMATION

The Texas Coastal Zone contains about 1900 miles of waterfront, 375 miles of which front on the open Gulf. The many miles of beaches and numerous bays and estuaries represent a tremendous resource for recreational activities. Almost 3 million tourists visited the Gulf Coast of Texas in 1969, and they spent more than 190 million dollars. Even so, the potential for recreational uses of the coastal area has hardly been tapped. The demand for recreational facilities has been growing rapidly during recent years, and it is expected to grow even faster in the future.

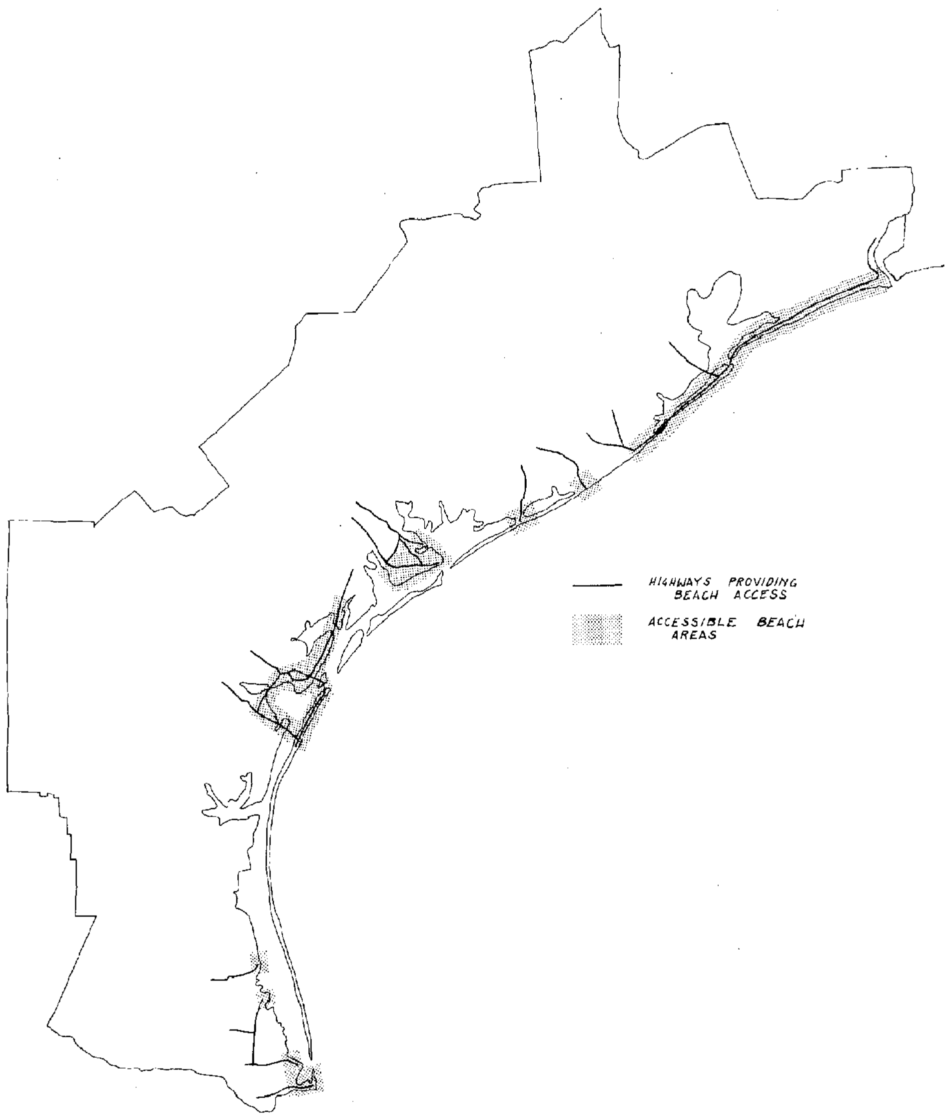
Much of the Texas coast is still relatively remote and desolate. Indeed, the remoteness and high degree of isolation is one of the features that attracts campers to Padre Island. A lack of access roads to the beach areas is the primary reason that relatively untouched beach areas still remain along the coast. Although access roads to the beach areas and the barrier reef presently exist at several locations (see Figure VI-5), only at Galveston and Corpus Christi are there high-level highways connecting the inland portions of Texas to the beaches. As the population of Texas increases, the demand for better access to the recreational areas along the coast will increase. Intercity travel parallel to the coast will also increase as the resident population in the Coastal Zone increases.

New highways in the Coastal Zone can significantly influence the type and extent of land development along the beach areas. The nature of future developments will differ depending upon the location and design of any new highway facility. Several alternative courses of action might be pursued relative to new highways paralleling the coast. Transportation and land-use considerations associated with each alternative are discussed in the following paragraphs.

ALTERNATIVES AND CONSEQUENCIES

No New Highways. One alternative course of action that might be followed is to prevent any further major highway construction in the coastal areas. However, in view of the projected increase in population of the Coastal Zone, it is clear that this alternative would result in increased congestion and a deterioration of service on existing highways. Thus, travel to and from the coast would be discouraged and many Texans would not be able to enjoy the potential recreational opportunities of the Coastal Zone.

FIGURE VI-5 BEACH AREAS WHERE HIGHWAY ACCESS IS NOW AVAILABLE

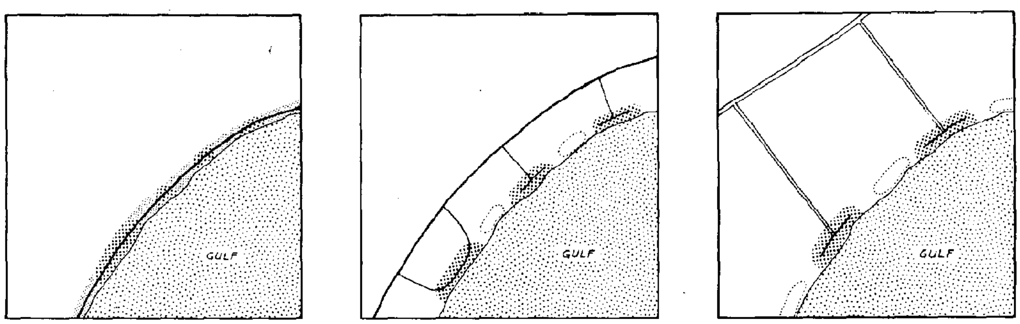


A lack of highway access to the coast is the primary reason that relatively untouched beach areas still remain. Although access roads presently exist at several locations, only at Galveston and Corpus Christi are there high-level highways connecting the inland portions of Texas to the beaches.

Beach Highway. A new highway might be constructed adjacent to the beach areas of the coast and barrier islands. This facility could be designed to be a major traffic artery; however, it probably would not be a controlled access freeway. Hence, a beach highway would make every section of the beach area highly accessible and it could provide for some increased intercity travel. Nevertheless, several undesirable consequencies would probably result from this alternative.

A highway located immediately adjacent to the beaches would stimulate continuous or spotted development along the entire coastline as depicted in Figure VI-6. Development along this highway might be expected to be similar to the strip development along Myrtle Beach, South Carolina and Panama City, Florida. Some areas of intense development, such as in the Miami Beach-Fort Lauderdale section of Florida, might occur, but it is unlikely that many facilities of this nature would be developed. Due to the increased accessibility of the entire coastline, few, if any, remote beaches would remain. In short, the construction of a beach highway would dramatically change the entire character of the Texas seashore.

FIGURE VI-6 LOCATIONAL CONSIDERATIONS FOR NEW HIGHWAY FACILITIES PARALLEL TO THE COAST



BEACH HIGHWAY

- along beach areas
- varying degrees of development along full length of beach area
- few, if any, natural, isolated beach areas remain

COASTAL HIGHWAY

- up to 15 miles inland from beach area
- nodes of development at access roads
- natural, isolated areas remain

INLAND HIGHWAY

- more than 20 miles inland from beach areas
- nodes of development at access highways
- natural, isolated areas remain but might be forfeited for future beach highway link

New highway facilities in the Coastal Zone can significantly influence the development of recreational facilities along the beach areas. The location of a highway is a critical consideration if any areas of seashore are to remain isolated and relatively untouched.

Coastal Highway. A new highway facility might be located generally parallel to the beach areas but a few miles inland in order to skirt some of the bays and marshlands. Under this alternative, management of the types of recreational developments would be facilitated by limiting the number and location of beach access roads extending from the coastal highway to the beach. In some instances, the coastal highway might actually follow the beach areas for some distance, but it would not provide continuous access to all beach areas.

This alternative would provide for improved access to the beach for recreational activities, and it would also provide a means for maintaining certain beach sections in their natural undisturbed state. A coastal highway would also provide for some improvement in intercity travel opportunities.

Inland Highway. An intercity freeway facility might be constructed generally parallel to the coast but ranging from 25 to 75 miles inland. This inland location would be better for constructing a modern high-speed freeway facility since it would skirt all bays, estuaries, marshlands, and ship channels. Also, it would be a more direct connection between major urban areas. Thus, an inland freeway would better serve the future intercity travel demands in the Coastal Zone.

Access to the beach areas could be provided by relatively long access roads connecting the inland freeway to the coast. Thus, the development of beach areas could be managed in the same manner as for the coastal highway. However, these access roads would be relatively long so that it would be difficult for tourists to conveniently visit two or more locations along the coast. This would undoubtedly lead to additional traffic on the beach and to pressures for improved highways immediately adjacent to the beach.

Two Facilities. These two distinct needs, intercity travel and beach access, might be served by two different highway facilities such as an inland freeway and a coastal highway. This alternative would require more total highway construction; however, it would offer some definite advantages over the other alternatives. Intercity travel demands could be better served by the freeway with some supplemental movement on the coastal highway. Access to the beach areas would be provided by the coastal highway, yet, portions of the beach could be kept remote and in their natural state. Also, the coastal highway could be developed in segments as the need occurs since the inland freeway would provide for longer trips parallel to the coast.

URBAN GROWTH

Presently, some 3 million persons live in urban areas located within the Coastal Zone. The urban population has more than doubled during the last 30 years, and it may double again in the next 30 years. Thus, massive new urban developments will be required; however, existing developed areas will not be abandoned. Future transportation problems in the Coastal Zone will largely depend upon how well the cities and the State manage to locate and shape new urban developments and transportation systems (See Figure VI-7).

NEW URBAN CENTERS

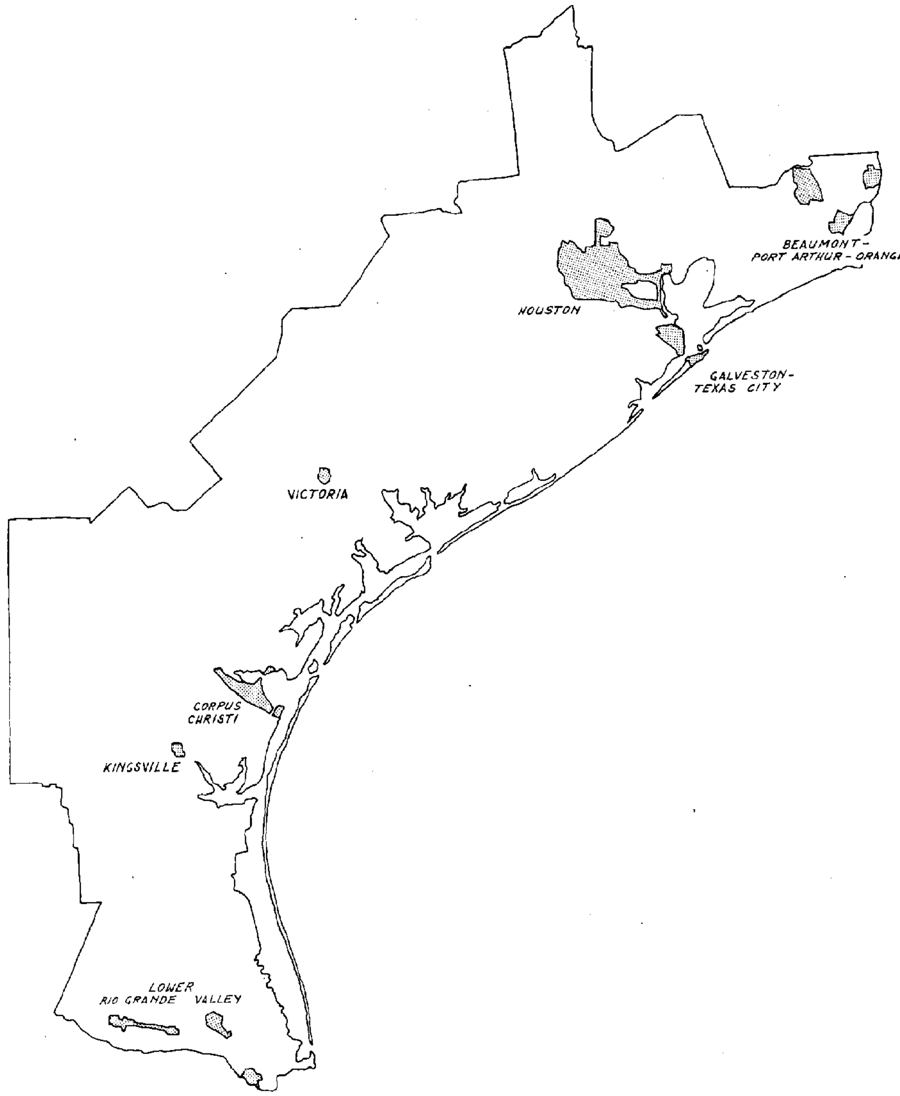
Two or three new urban centers might possibly be developed along the Coastal Zone in order to disperse the population and minimize the amount of redevelopment required in existing cities. If radically different urban forms are to be developed in the Coastal Zone, they must be started at new locations. However, if future residential development is also to be primarily single family dwelling units, any new cities that are developed will be similar to existing cities.

Aggressive steps on the part of the State would be required in order to stimulate major urban developments in new locations. Intercity transportation facilities would have to be provided to the new location and numerous industries would have to be enticed to locate at the new site. The construction of a super-port in a relatively undeveloped portion of the Coastal Zone could provide the nucleus for a new urban center. However, the overall cost of transportation facilities to serve new urban centers would probably be greater than for properly planned expansions of existing urban areas.

EXPANSION OF EXISTING CITIES

Without stringent external controls, new urban development will tend to occur around existing urban centers. Urban growth can be accommodated in relatively small increments when added to existing cities since the basic transportation facilities to serve it already exist. Indeed, very few additional intercity transportation corridors would be required under this alternative; however, the capacity of existing corridors would need to be increased significantly. Careful planning and new implementations procedures will be required if the new urban development is to be compatible with existing urban transportation systems.

FIGURE VI-7 EXISTING URBAN DEVELOPMENT IN THE COASTAL ZONE



The urban population of the Coastal Zone may double in the next 30 years. Future transportation problems will largely depend upon how well the cities and the State manage to locate and shape new urban developments. Two or three new urban centers might be developed or all of the growth might occur around existing cities. If properly done, either alternative can function well.

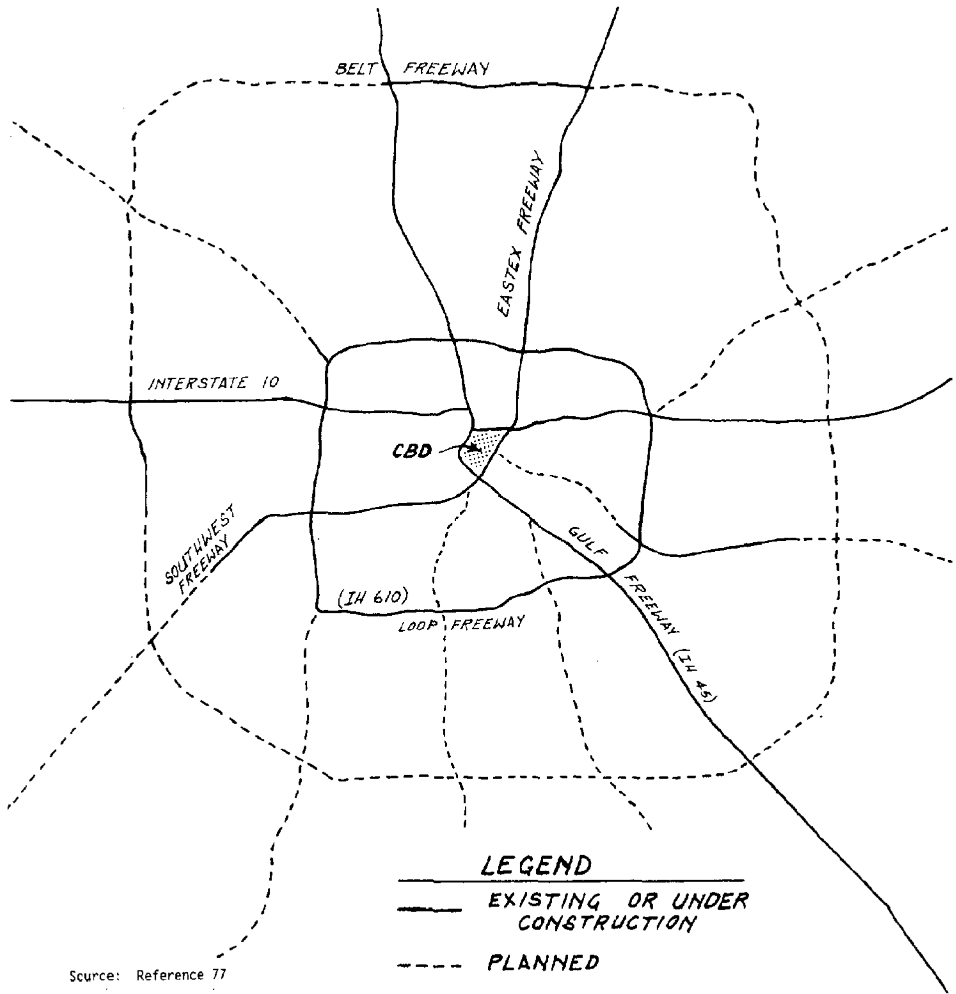
Houston. The Houston area will face some unique problems in accommodating future growth. Its existing low-density urban form is oriented toward an automobile-based transportation system, and yet, the intensity of development in downtown Houston has already exceeded that which can be served adequately by automobiles alone. The established radial-circumferential freeway system tends to stimulate the development of a strong central focal point (See Figure VI-8). The freeway system and existing urban form of Houston has progressed so far that there appears to be very limited opportunity to develop a second focal point that can rival the existing city center. Thus, it appears that Houston must try to develop an urban form in which mass transportation can effectively supplement the automobile if it is to support additional downtown development. This will, however, necessitate significant change in the overall pattern of development.

Almost 30% of the population of Houston currently lives in multi-family housing. If this trend continues in the future, medium density areas can be developed which can be served by Bus Rapid Transit. Or, high-density corridors might possibly be developed that could be served by Rail Rapid Transit. Another alternative that Houston might consider is the development transportation terminals at dispersed locations which are connected to downtown by a Skybus or a Personal Rapid Transit System. Whatever alternative is selected, careful planning and land management will be needed to successfully implement it.

Beaumont-Port Arthur-Orange. The Beaumont-Port Arhtur-Orange area is already becoming one large metropolitan area with three principal focal points. If growth is properly directed, this urban area can develop into an excellant example of the multiple focal point concept with a transportation system which could serve several million persons. These three downtown areas are presently connected by major highways and freeways that form a triangle. However, additional capacity along these corridors will be needed in the future so expansion problems could be avoided if additional right-of-way were acquired now. Eventually, these corridors may need some form of mass transportation between the three focal points.

Other Cities. Most of the existing urban centers in the Coastal Zone have a great deal of flexibility in the type of urban form that they might choose for the future. About the only constraint is that the new development should be kept compatible with existing automobile-based transportation systems. However, if the entire arterial street and freeway system is designed to serve low density single-family housing developments, severe problems may occur if a sizeable amount of multi-family apartments are built. Thus, careful planning and inovative land management practices will need to be implemented in cities that are aiming at an automobile-based urban transportation system.

FIGURE VI-8 EXISTING AND PLANNED FREEWAY SYSTEM FOR HOUSTON



Source: Reference 77

The established radial-circumferential freeway system of Houston tends to stimulate development of a strong central focal point. The intensity of development in downtown Houston has already exceeded that which can be adequately served by automobiles alone. Thus, Houston must seek to develop an urban form in which mass transportation can supplement the automobile.

GUIDELINES FOR FUTURE DEVELOPMENT

URBAN TRANSPORTATION

CITY SIZE CONSTRAINTS

The principal decision in regard to urban development is the desired nature and character of the area. Various cities might differ widely in their pattern and intensity of development and still provide a high degree of mobility, at reasonable cost, for the urban resident. However, once the desired character is identified, compatible land development and transportation policies must be evolved and implemented in a coordinated manner.

Different urban transportation systems need, and in turn can accommodate, different amounts and intensity of development in order to achieve economical operation. This in turn influences the minimum and maximum functional size (land area and population) of an urban area. Also, the number, size, and arrangement of focal points further influences the maximum city size that can be served by various modes of transportation.

All of the cities in the Coastal Zone have developed at relatively low average population densities since most of the residents live in single-family dwelling units. This type of development can best be served by the automobile operating on a well-designed system of streets and freeways. Thus, if future development is similar in nature, urban transportation systems will continue to be based primarily upon the automobile.

Many of the urban centers in the Coastal Zone currently have little or no urban freeway system. With a properly designed system of arterial streets, a city can grow to sizable proportions before a freeway system is needed for general urban mobility. The limiting factor is the maximum time that would be acceptable for traveling between any two locations within the urban area during off-peak periods.

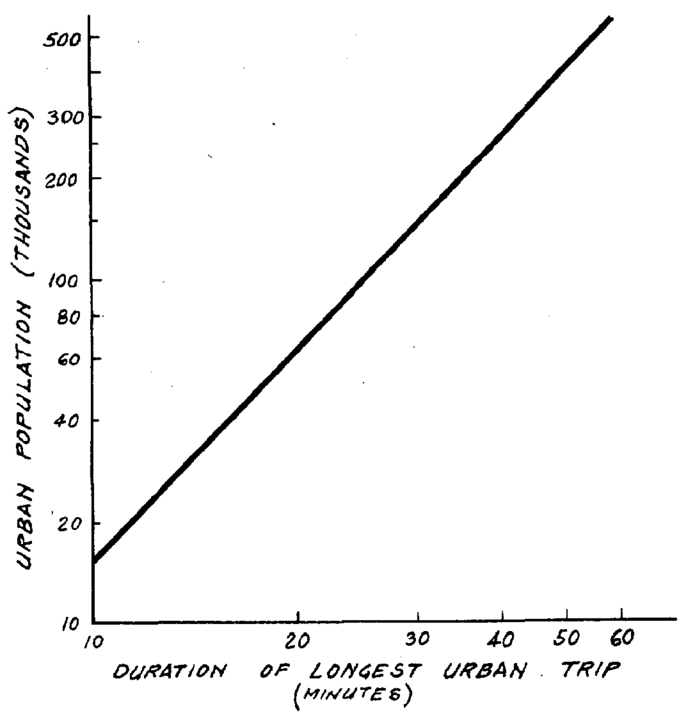
Of course, specific conditions will vary from city to city, but the curve shown in Figure VII-1 can be used as a general guideline as to how large a city can be before it needs an urban freeway system.

This relationship between total population and maximum travel time was calculated based upon the following assumptions:

1. Average population density = 2500 ppsm;
2. Grid pattern of arterial streets with a spacing of one mile;
3. Average speed on arterials = 30 mph including stops; and
4. Maximum length urban trip would be from one corner of the grid pattern to the corner diagonally opposite.

As can be seen from the curve, the maximum urban trip time in a city of 250,000 persons would be 40 minutes. If a maximum urban trip time of one hour is acceptable, a city of more than 500,000 population can be served by arterial streets without a freeway system.

FIGURE VII-1 MAXIMUM CITY SIZE WITHOUT AN URBAN FREEWAY SYSTEM



With a properly designed system of arterial streets, a city can grow to sizeable proportions before a freeway system is needed for general urban mobility. The limiting factor is the maximum trip time that would be acceptable for traveling between any two locations within the urban area.

Once a city is large enough to need an urban freeway system, the next constraint to be considered is the maximum population that can be served by a single urban focal point. The central business district (CBD) or "downtown" has historically been the area with the greatest level of development within a city; consequently, it is also the largest traffic generator within the urban area. Different urban transportation systems can accommodate various levels of intensity of development within such a focal point, and the size of the city is related to the intensity of the CBD.

In all Coastal Zone cities, walking is the only mode of transportation currently used for circulation within the CBD. Thus, the current size of the CBD is limited to that which can be served by a pedestrian circulation system - about one square mile. Most of the CBD's in Coastal Zone cities, as well as in other Texas cities, cover about one square mile of land area.

The maximum number of persons accumulated within the CBD at any one time, usually at mid-day, varies with the population of the urban area. As the total population increases, the daytime population density of the CBD also increases. Consequently, the type of transportation system needed to handle commuter traffic to and from the focal point varies with population. The relationship between city size, CBD population density, and urban transportation systems is presented in Figure VII-2.

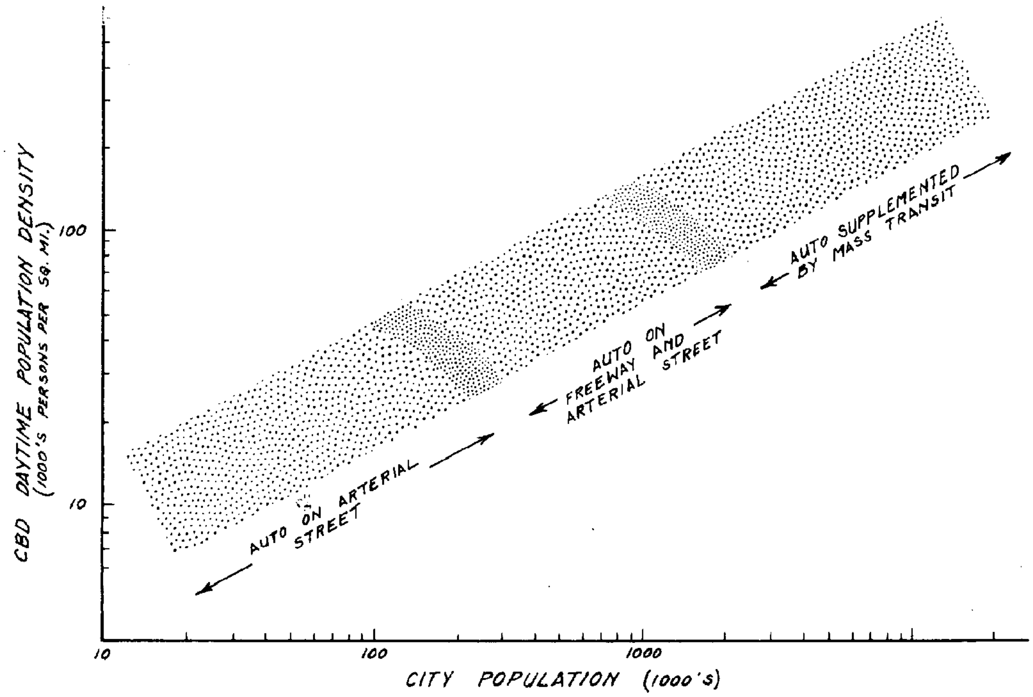
The constraints on the intensity of CBD, or focal point, development that can be served by various transportation systems were calculated based upon the following assumptions:

1. Ideal arterial street system;
2. Six 8-lane freeways serving focal point;
3. 40% of total number of persons accumulated in focal point enter during peak-hour;
4. Average automobile occupancy = 1.4 persons per auto during peak-hour; and
5. Half of the freeway traffic is going to the focal point.

The limiting factor for CBD's covering about one square mile is the capacity of the arterial streets entering the concentrated area. Thus, additional freeway capacity has no effect on the number of persons that can enter the CBD.

According to these calculations, cities with populations up to 300,000 persons (corresponding CBD density of 50,000 persons per square mile) can be served adequately by automobiles operating on arterial

FIGURE VII-2 MAXIMUM URBAN POPULATION PER FOCAL POINT SERVED BY VARIOUS TRANSPORTATION SYSTEMS



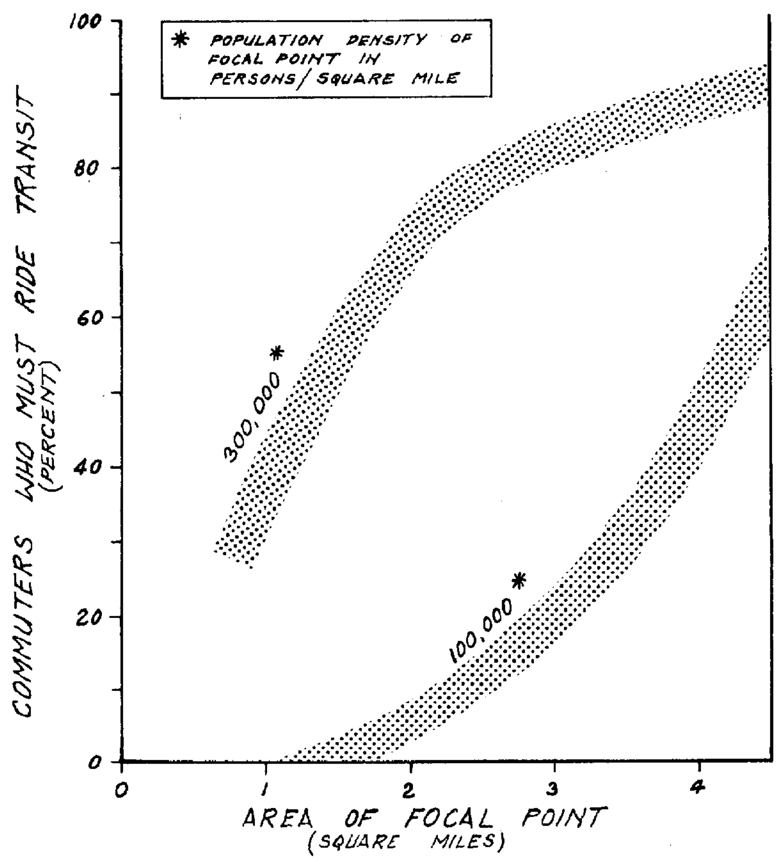
The central business district (CBD), located at the focal point of a city, is usually the largest traffic generator within an urban area. Different urban transportation systems can serve various levels of development within such a focal point, and the intensity of development within the focal point is related to the total urban population surrounding it. Thus, the type of transportation system needed to serve commuter traffic to and from the focal point varies with population.

streets only. If an extensive freeway system is provided to supplement the arterial streets, a total urban population of about 1 1/2 to 2 million surrounding a single focal point (with a corresponding density of about 130,000 ppsm) can be served by the automobile. It is interesting to note that for CBD population densities exceeding about 130,000 ppsm, additional modes are needed to supplement the pedestrian-based internal circulation system. Thus, larger urban areas must either develop multiple focal points or they must supplement both the automobile-based commuter system and the pedestrian-based circulation system serving the single focal point.

The daytime population density in CBD's of Texas cities appears to increase to about 100,000 ppsm before the intense development begins to spread out beyond the one square mile area. Then both the size and the density of the CBD increase. (15). The daytime population density on Manhatten Island has decreased in recent years so that now it is about 300,000 persons per square mile (78). Thus, a population density of 300,000 ppsm might be considered the maximum for modern CBD developments. As the level of development within the CBD is expanded beyond 100,000 ppsm and one square mile, the dependence of commuters upon mass transportation increases.

The percentage of daily CBD commuters that would have to use mass transportation is indicated in Figure VII-3 for various levels of CBD development. The term "mass transportation" does not necessarily denote rail rapid transit. Indeed, these curves are based upon buses using existing freeways as the mode of mass transportation. If 90% of the

FIGURE VII-3 IMPORTANCE OF MASS TRANSPORTATION TO HIGHLY DEVELOPED FOCAL POINTS



As the level of development of a focal point (CBD, etc.) increases, the dependence of commuters upon mass transportation increases. Also, additional modes of transportation are needed to supplement walking in the internal circulation system.

commuters are willing to ride buses to work, a total CBD daytime population of more than 1,200,000 persons can be served by the same street and highway facilities designed for a CBD population of only 100,000 persons.

Coastal Zone cities can avoid major transportation problems in the future if these relationships between urban size, form, and transportation systems are considered in the early stages of urban development and plans are adjusted accordingly. General guidelines concerning city sizes that can be accommodated by various modes of transportation are summarized in Table VII-1.

TABLE VII-1 GUIDELINES FOR SIZE OF CITIES THAT CAN BE SERVED BY VARIOUS MODES OF TRANSPORTATION

		Total Urban Population	
Primary Mode Of Transportation	Supplementary Modes In Concentrated Areas	Minimum Practical Size	Maximum Per Focal Point
Walking	None	None	40,000
Auto on Arterial Streets	Walk	None	300,000
Auto on Freeways and Arterials	Walk & Elevators	300,000	2,000,000
Rail Rapid Transit	Walk & Elevators	1,000,000	2,000,000
Rail Rapid Transit	People Mover	2,000,000	6,000,000

Peak-hour demands for persons traveling to or from a focal point limit the size of an urban area that can be served by various modes of transportation. Increasing the number of focal points enables an auto-oriented city to grow much larger. The greater Los Angeles area, with a total population of some nine million, is a good example of an urban area with multiple focal points that is adequately served by the automobile.

FUNCTIONAL CLASSIFICATION OF STREETS

People today tend to associate the need for streets with the automobile; however, cities developed centuries ago had street patterns that resemble those in modern auto-oriented cities. Indeed, the Mayan civilization in Mexico and Central America developed without any form of wheeled transportation, and yet, their cities had extensive street systems. Even if the automobile is abandoned as a mode of urban transportation, cities will still need a basic street system to serve the same functions that streets serve today.

Urban streets serve a variety of functions which are important to the overall operation of a city. Major functions provided by a street include the following:

1. Movement of traffic;

2. Access to abutting property;

3. Drainage;

4. Utilities (water, sewer, gas, electricity, telephone, etc.);

5. Separation of land use;

6. Light and air (open space) in highly developed areas such as downtown; and

7. Other related traffic functions (parking, loading, etc.).

Most of these functions are compatible and can be accommodated simultaneously on properly designed streets; however, the functions of movement and access are competitive in nature so a single facility cannot be designed to provide a maximum of each.

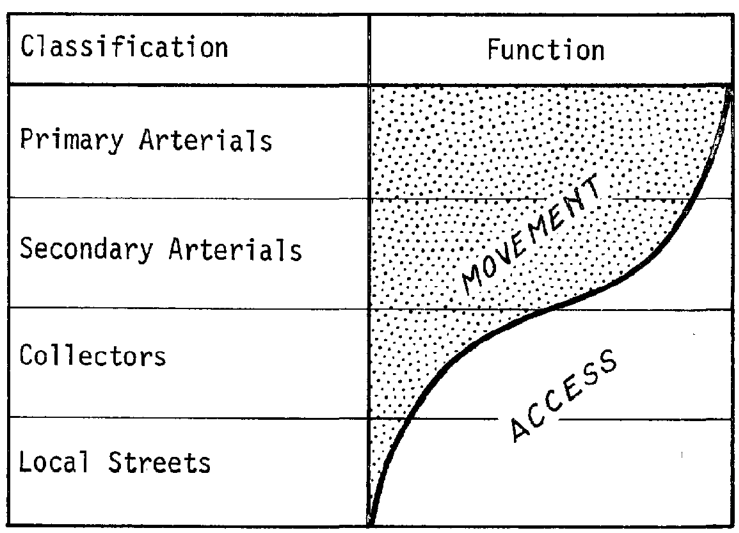
Some of the problems with current street systems have evolved because of a lack of awareness of the competing nature of the access and movement function. A classification of streets according to the relative importance of these two functions can be extremely useful in developing plans for urban street systems. Street and highway facilities can generally be grouped into the following four classifications: primary arterials, secondary arterials, collectors, and local streets. The relative importance of the movement and access functions to each classification is depicted in Figure VII-4. Definitions of these classifications are presented in the following paragraphs.

Primary Arterials. Primary arterials are the major traffic carriers in the system; therefore, the movement function should be maximized at the expense of the access function. These facilities carry traffic to and from the major activity centers within the city. They characteristically serve the long urban trips and carry high traffic volumes. Although primary arterials normally account for no more than 10% of the total street mileage, they accommodate more than half of the urban travel. The primary arterial classification includes freeways, expressways, and surface streets. The degree of access control varies with the nature of the facility, but on all primary arterials, the movement function is far more important than the access function. Thus, driveways should not be permitted to connect directly to primary arterials.

Secondary Arterials. Secondary arterials primarily serve movement, but they also can provide for some access to abutting properties. These facilities distribute traffic to and from the primary arterials. They serve trips of moderate length at a slightly lower level of service than the primary facilities. A secondary arterial might connect some traffic generators such as residential neighborhoods, community shopping centers, smaller industrial areas, and public facilities. A limited number of driveways can be accommodated on secondary arterials.

Collectors. Collector streets carry traffic between the arterial street system and the local streets. Their movement function is to concentrate traffic before it intersects with arterial streets so they do not serve long trips. Indeed, collectors should not provide a direct connection through a neighborhood that could serve through traffic. Although the movement function of a collector is important, its primary function is to provide access to the adjacent land. Driveways can be accommodated at frequent intervals on collector streets providing they are properly designed and located.

FIGURE VII-4 FUNCTIONAL CLASSIFICATIONS OF STREETS



Some of the problems with current street systems have evolved because of a lack of awareness of the competitive nature of the access and movement functions. A functional classification of street facilities can help planners avoid such problems in the future.

Local Streets. Almost three-fourths of the mileage in most urban street systems is local streets, yet they carry less than one-fourth of the urban travel. The primary function of local streets is to provide direct access to individual abutting properties. Usually, only persons with trip destinations or origins on a local street have a need to travel on the facility. Thus, the movement function is minor compared to the access function. Local streets need no access controls.

ACCESSIBILITY VS DIRECT ACCESS

In order for urban street sytems to effectively serve travel needs, the functional classification of each facility should be identified, and the facility should be designed and used accordingly. Access controls are needed along arterial streets in order to protect their movement function. There is often public opposition to access controls, but much of the opposition subsides once the land owners recognize the difference in access and accessibility as depicted in Figure VII-5.

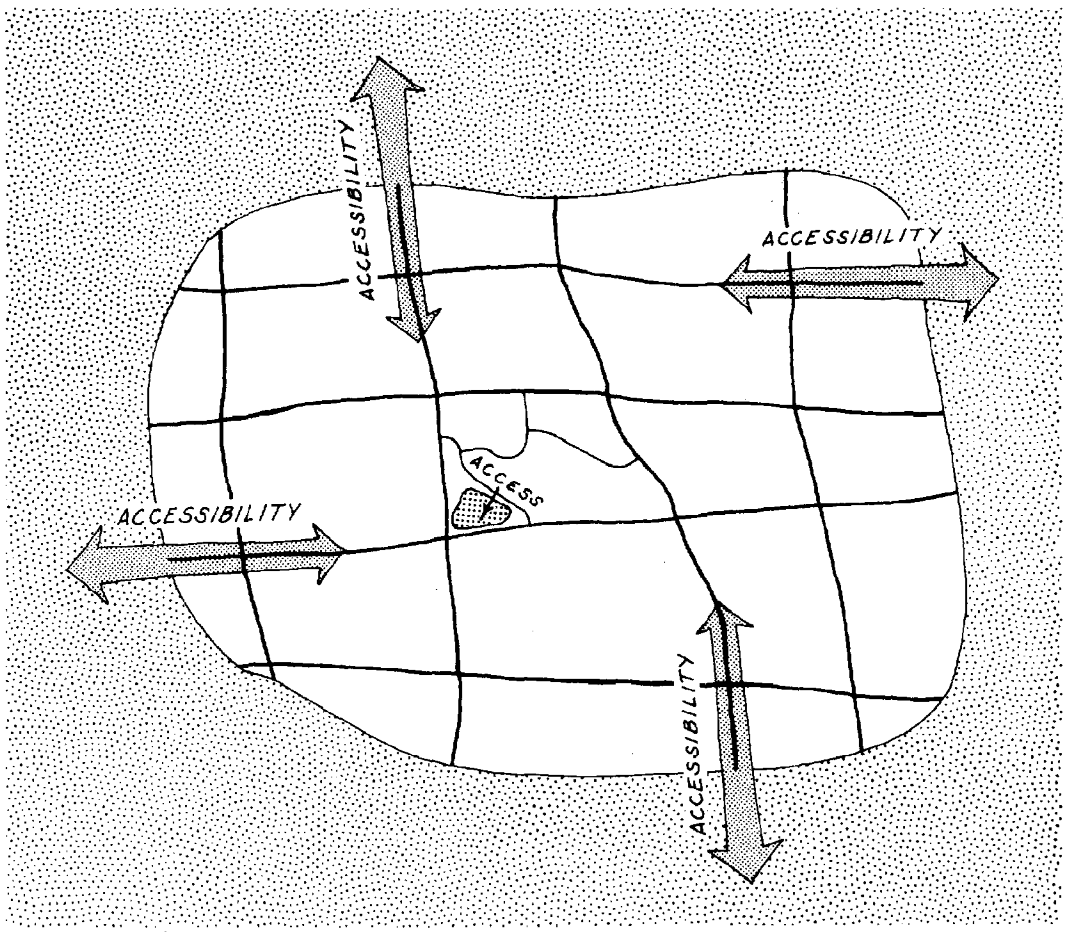
Strip commercial developments have often evolved along arterial streets. Commercial firms are attracted to these locations because the arterial facility provides good accessibility from a wide market area. Large volumes of persons travel the arterial every day so a firm located adjacent to an arterial is exposed to many potential customers. It is only natural then that an entrepreneur would want to locate his firm so that it has a direct driveway access to a primary arterial. However, everyone else wants to do the same thing until eventually the arterial street loses its original attraction - good accessibility.

Frequent access points, driveways and intersections, along an arterial street result in numerous turning manuevers. Turning vehicles must use traffic lanes for acceleration and deceleration lanes; therefore, they greatly hinder the flow of traffic along the arterial. Also, the turning movements are made at uncontrolled and hazardous locations necessitating a reduction in operating speeds from the desirable 45 mph to 30 mph. Hence, the capacity and the level of service that the arterial street needs to provide for traffic movement is destroyed by numerous direct access points.

Historically, the life cycle of an arterial street goes from a new facility with a high level of service to a strip commercial development with severe traffic congestion. The cost of acquiring additional right-of-way to increase the traffic movement capacity of the facility becomes prohibitive so a new bypass is constructed. Then the process is repeated so that today bypasses are being built to bypass the bypass that bypassed the bypass. Each bypass is in a less desirable location that the previous facility; consequently, it provides a lower level of service than could have been provided if the movement function of the arterial street had been protected.

In order to avoid such occurrances in the future, adequate right-of-way should be acquired for future flexibility and direct access to the facility must be controlled. The function of an primary arterial street is to provide good accessibility over a wide portion of the urban area. Direct access should be provided from facilities with lower levels of classification.

FIGURE VII-5 ACCESSIBILITY VS DIRECT ACCESS



Primary arterials provide good accessibility over a broad portion of the urban area. Direct access points along an arterial street destroy its capability for traffic movement. Commercial firms seek locations with good accessibility to a broad market area. Thus, it is in their best interest to take direct access from other streets near the arterial rather than to destroy the accessibility provided by the arterial.

LIMITED ACCESS SUBDIVISIONS

Modern residential subdivisions probably offer the easiest opportunity for implementing the functional classification concept in street design. Progressive developers have already recognized the undersirable features of houses fronting on streets serving through traffic both from the homeowner's point of view and from a traffic standpoint. Recent trends toward larger scale developments (50 acres or more) have increased the opportunity for developers to implement limited access subdivision designs.

Such subdivisions eliminate all residential driveway connections to arterial streets. Streets are designed so that residential lots either back up to the arterial or face an intersecting collector street (See Figure VII-6). A limited number of collector streets intersect

FIGURE VII-6 LIMITED ACCESS SUBDIVISION

Limited access subdivisions result in better traffic operations on the arterial streets, and they provide a more relaxed atmosphere in the residential area. Recent trends toward larger scale developments have increased the opportunity for developers to implement limited access subdivisions.

the arterials bordering the subdivision at spacings of about 1/4 mile. The limited number of entry points result in improved traffic operations on the arterial, and they provide an opportunity for the developer to establish an identity for the subdivision.

Modern limited access subdivisions offer a totally different living environment than older residential areas with gridiron street patterns. The curving, short residential streets tend to slow down traffic and yield a more relaxed atmosphere. Also, traffic safety studies have shown that the accident rates in limited access subdivisions are only about 15% as high as in areas with gridiron street patterns. One major reason for reduced accident rates in limited access subdivisions is that the street pattern lends itself to the use of numerous 3-legged "Tee" intersections. Accident rates at 3-legged Tee intersections are less than one-tenth the rate for typical 4-legged intersections.

Future residential developments in the Coastal Zone can provide a better living environment as well as improved traffic conditions if the following considerations are observed:

1. Limited access points on collector streets spaced at quarter-mile intervals result in better subdivisions;

2. Collector streets should not be continuous from one major arterial to another;

3. 3-legged Tee intersections are preferred to 4-legged cross intersections within the subdivision;

4. Y-type and acute angle intersections should be avoided; and

5. Guidelines concerning the maximum number of dwelling units served by various types of residential streets should be followed (See Table VII-2).

PLANNING STREET SYSTEMS

Once the primary function of each street classification has been established, desirable characteristics of facilities in each classification can be identified. Such items as the pattern for various types of facilities, the spacing between them, minimum right-of-way requirements, number of lanes, normal operating conditions, and intersection spacing should be considered early in the planning process.

Cities in the Coastal Zone are predominantly comprised of single family dwelling units so that the resulting overall population densities range from 2000 to 3000 persons per square mile. Primary arterial

TABLE VII-2 GUIDELINES FOR MAXIMUM NUMBER OF DWELLING UNITS SERVED BY RESIDENTIAL STREETS

Street Type	Maximum Number Of Dwelling Units
Cul-de-Sac	20-25
Local Street Loop	40-50
Collector Street (from its connection to arterial)	200-300

The primary function of residential streets is to provide access to individual parcels of land. Minimum standard street widths are usually more than adequate to handle the movement function if the street does not serve too many dwelling units.

streets spaced at about one mile intervals usually provide a good level of mobility for urban areas with this population density. Of course, the spacing of primary arterials should be adjusted to conform to variations in population density within the urban area.

Uniform spacing of primary arterial streets is facilitated by adopting a grid pattern of arterial streets. However, the overall grid pattern should not be rigidly maintained despite topographical features and variations in population density. The overall pattern should be flexible, but all intersections of major streets should be at right angles.

Local streets should not be permitted to intersect primary arterials. Numerous street intersections deter the movement function of arterials the same as driveways. Thus, only secondary arterials and collectors should be designed to intersect primary arterials. It is very important that intersection spacing be held relatively uniform on primarily arterials. Intersection spacings of 1600 to 2000 feet are amenable to the installation of progressive signal systems designed for operating speeds of 35 to 45 miles per hour.

The freeway represents the highest level facility in the primary arterial classification. It serves longer urban trips and provides a higher level of service than surface arterials. Thus, freeways can be spaced at wider intervals than surface arterials - usually at 4 to 6 mile intervals. The minimum functional spacing of freeways near major focal points is about 2 miles.

If a grid pattern of arterial streets is used, a radial-circumferential pattern of freeways might be superimposed to yield a higher level of overall urban mobility (similar to the existing system in Houston). However, radial-circumferential freeway systems tend to stimulate the development of a strong focal point which can necessitate the use of additional modes of transportation when the population of the urban area approaches 2 million persons. Multiple focal point urban forms, which can accommodate larger populations with an automobile-based transportation system, can be developed by shaping the freeway system to serve several focal points.

Typical urban areas do not usually need a "system" of secondary arterials. Rather, secondary arterials are usually installed to serve specific needs in various areas within the city. The type of land use and expected travel demands are usually known when a secondary arterial is designed; however, the right-of-way should be sufficient to provide some degree of flexibility in the future.

Guidelines concerning critical considerations in planning urban street systems are summarized in Table VII-3. If these guidelines are followed, the resulting system should provide a high level of mobility for cities with population densities characteristic of the Coastal Zone. However, good planning is just the first step. Proper facility designs and appropriate land use controls are also necessary in order to implement and maintain an effective urban transportation system.

TABLE VII-3 GUIDELINES FOR PLANNING URBAN STREET SYSTEMS FOR COASTAL ZONE CITIES

Classification Of Facility	Minimum Right Of Way Width, Feet	Number Of Through Lanes	Median Width, Feet	Normal Operating Speeds, mph	Spacing Between Facilities	Intersection Spacing
Primary Arterials:						
Freeways	300	6-10	30-70	45-55	4-6 miles	1-2 miles
Surface Arterials	125	4-8	16-30	35-45	1 mile	1600-2000 ft.
Secondary Arterials	100	4-6	None	30-40	N/A	1200-1600 ft.
Collectors	60	2-4	None	20-30	N/A	N/A
Local Streets	50	2	None	10-20	N/A	N/A

Planning is an essential step in the development of a good urban street system; however, this is just the first step. Proper facility designs and appropriate land use contols are also necessary in order to implement and maintain an effective urban transportation system.

TRANSPORTATION CORRIDORS

Major transportation facilities represent a permanent commitment to the movement of persons and goods between areas of concentrated activity. The need for this transportation function will continue as long as the activity areas exist. History abounds with examples of overland transportation facilities that have been successively upgraded to provide improved service. Many of the original Roman roads now have modern highways or railroads on the same alignment. The Michigan Road in Indiana, the Cumberland Road between Maryland and Illinois, El Camino Real in California, and the Old San Antonio Road in Texas are examples of old highways which have been adapted to changing needs and standards of service.

A comparison between an old street and highway map and a modern one for almost any city will reveal numerous arterials which have been in service since the earliest days of the city. Washington Avenue and Liberty Street in Houston are examples of such permanence. These arterials are two of the five roads radiating from the original City of Houston.

The first major transportation facility installed to connect activity areas is usually located on the most desirable alignment. Thus, subsequent improvements in capacity and level of service could best be accomplished along the same alignment. However, narrow right-of-ways and extensive land development along the original facility often make it less expensive to abandon the old facility and to use an entirely new right-of-way (when expansion of capacity is necessary.) This is frequently the situation with the Interstate System where a new fully controlled access highway connects the same major activity areas as an existing route within the same general travel corridor. Indeed, the new facility is often within a few hundred yards of the old facility. However, each new route is usually in a less desirable location than the older route.

A transportation corridor might serve numerous different modes of transportation and different levels of service, but its function will be needed for centuries. After all, the three primary modes of surface transportation being used today (railroads, pipelines, and motor vehicles) are newer than many of the corridors in which they are located. Railroads did not come on the American scene as a major mode of transportation until after the Civil War. Today, barely 100 years later, the total mileage of rail routes has already peaked out and many lines are being abandoned to other modes. Pipelines came of age after the beginning of the twentieth century so this mode of transportation is only 70 years old. Motor vehicles, automobiles and trucks, became an effective mode of transportation less than 50 years ago - during the 1920's. Who knows what modes of surface transportation will be used 100 years from now!

Future transportation needs in the Coastal Zone can be met more effectively if the cities, the counties, and the State embrace the concept of permanent transportation corridors. Sufficient right-of-way should be acquired to permit concurrent use by several modes of transportation and to provide for future flexibility. Once a transportation corridor has been so designated, its functionality should be protected by appropriate land development controls. Critical steps in the evolution of permanent transportation corridors are summarized in Table VII-4.

TABLE VII-4 STEPS TOWARD PERMANENT TRANSPORTATION CORRIDORS

1. Identify major intercity and urban transportation corridors for future.
2. Acquire sufficient right-of-way as soon as possible.
3. Protect transportation function through appropriate land use controls.
4. Locate all new surface transportation facilities, whatever the mode, within the corridor connecting the two activity areas being served.
5. Reserve additional land near intersections of major corridors for future transportation terminals.

Future transportation needs in the Coastal Zone can be met more effectively if the cities, the counties and the State embrace the concept of permanent transportation corridors. Implementation of this concept will provide increased flexibility and should result in less total land area devoted to transportation.

Of course, one of the first questions that will be asked is how much right-of-way is needed. A major intercity transportation corridor, (such as the ones between Houston and Dallas, Houston and San Antonio, and parallel to the coast) might contain a six-lane freeway, two freight rail lines, a high-speed passenger rail facility, and several pipelines. Thus, right-of-way widths of 1/4 mile or more would be appropriate major urban corridors might contain a ten-lane freeway, a fixed-way transit line, and some goods movement facilities (rail lines, truck roads, conveyor belts, etc.); thus, right-of-way widths of 1000 feet or more might be considered.

If the concept of excess right-of-way acqusition becomes an accepted principle, public agencies will have much better control over land use within the corridor. For example, if the additional right-of-way is not expected to be needed for transportation purposes for 20 years or more, it could be leased to private development for specific time periods with stipulations concerning land-use types, intensities, design, and access arrangements. Most commercial facilities that are attracted to major highways (motels, restuarants, service stations, etc) have expected economic life spans of twenty years or less. Thus, fifteen- or twenty-year leases should be acceptable to private investors, and they would protect the corridor for future public needs.

TRANSPORTATION TERMINALS

A transportation terminal is a location where two or more modes can interchange traffic. For example, a typical Texas seaport provides an interface between ocean-going traffic and inland waterways, rail lines, pipelines, and highways. Each of these connecting modes is an important element of the total transportation service provided by the port. Unfortunately, the needs of connecting complimentary modes of transportation are often overlooked in the design of major transportation terminals. Terminal facilities are oriented primarily toward serving one mode, as the name implies (airport, seaport, train station, etc.), but the basic function of the terminal is to provide for modal interchanges so the other modes must be considered.

Future plans for transportation terminals in the Coastal Zone should include due consideration of the various modal interfaces that should occur there. Potential modal interchanges that should be considered for various types of transportation terminals are listed in Table VII-5. Of course, the interfaces listed in this table are based upon existing modes of transportation and existing traffic characteristics. Future changes in transportation technology may create new modal interfaces to be considered.

TABLE VII-5 POTENTIAL MODAL INTERCHANGES AT FUTURE TRANSPORTATION TERMINALS

Type Of Transportation Terminal	Modes Of Transportation					
	Highway	Rail	Water	Pipeline	Air	Mass Transit
Airports						
General Purpose	Trucks, Cars & Buses	Freight & Passenger			V/STOL	RRT or BRT
All Cargo	Trucks	Freight				
V/STOL	Cars & Buses					RRT or BRT
Seaports						
Ocean Going	Trucks, Cars & Buses	Freight & Passenger	Barge	Crude & Products		?
Barge	Trucks	Freight		Crude & Products		
Intercity Bus Station	Cars, Trucks	Passenger				Local Bus or Rapid Transit
Urban Transit Station	Cars & Buses				V/STOL	Other Modes
Railroad Yards & Station	Trucks, Cars & Buses		Barge	Crude & Products		Bus or Rapid Transit

A transportation terminal provides of interchanging traffic between two or more modes. Future transportation plans should consider the various modes that should serve major transportation terminals.

CONCLUSIONS AND RECOMMENDATIONS

This study constitutes an overall evaluation of the total transportation system serving the Coastal Zone of Texas. One purpose of the study is to identify actions that the State might take to avoid future problems and to instigate solutions to existing problems. Significant findings of this research are enumerated as conclusions in the following subsections: Water Transportation, Transportation/Land-Use Relationships, Planning and Implementation Procedures, Transportation Corridors, Environmental Considerations, and Recreational Travel. Specific recommendations for State action relative to Coastal Zone transportation are presented in each subsection.

WATER TRANSPORTATION

CONCLUSIONS

Water transportation is important to the entire State. It seems that few Texans recognize the importance of water transportation to the State, but almost three-fourths of all tons of goods shipped from Texas, by all modes except pipeline, travel by water. Indeed, Texas rivals New York as the leading sea-faring state in the nation. Texas ports handle a total of almost 200 million tons of goods annually. Several major sectors of the Texas economy including petrochemicals, metals, mining, and agriculture rely heavily upon this form of transportation. Thus, the viability of the water transportation industry should be a matter of concern to the entire state.

Texas ports need deeper facilities. The maximum depth currently available at any Texas port is only 40 feet; therefore, they cannot serve ships exceeding 50,000 deadweight tons. The average size tanker being built today is over 100,000 deadweight tons and the sizes are rapidly increasing. The net result is that Texas ports cannot serve economical size ships today, and unless something is done, they will not be able to compete in future ocean traffic.

Congestion on Louisiana segment of canal concerns Texas. The Texas portion of the Gulf Intracoastal Canal is connected to an extensive inland waterway network serving the heartland of the nation. Inland waterway traffic in Texas had been increasing rapidly over the last 20 years until 1967 when it leveled off. Traffic congestion in the Louisiana portion of the canal was probably responsible for this abrupt leveling off in growth rate. There are several locks along the Louisiana segment of the canal and they are now operating near their ultimate capacity. The net result is that future growth in Texas economic activities oriented toward the inland waterway system will be stymied unless this transportation problem is alleviated.

RECOMMENDATIONS

State agency for water transportation is needed. It is recommended that Texas create a state agency for water transportation. The purpose of this agency should be to help solve problems facing the water transportation industry serving Texas. Such a state agency can be more effective in forcing remedial actions than can the various ports working individually. Thus, the interests of the entire state relative to water transportation can be better served by a state agency.

Further study of super-draft ports is needed. The Corps of Engineers is currently conducting a study of the feasibility of constructing superports to serve the northeastern seaboard and the Gulf Coast. However, this study will not be completed for three years, and even then, it will not answer some of the questions that are vital to Texas. A super-port study is needed which would complement the work of the Corps of Engineers but would answer questions that are unique to Texas. This study should include the following tasks:

(1) Evaluate the various alternative approaches to identify major problems of each that would require attention of the state;

(2) Analyze ocean-borne commodity flow to and from Texas today and project future demands;

(3) Evaluate the changes in other modes of transportation needed to support increased ocean traffic under each of the alternatives studied;

(4) Identify significant economic, industrial, and social considerations relative to the specific location of super-draft port facilities along the Texas Coast;

(5) Work closely with the Corps of Engineers to minimize duplication of effort and maximize effectiveness of both studies; and

(6) Develop a plan of action for state efforts toward maintaining a viable ocean-going transportation industry in Texas.

Further study of inland waterway problems is needed. A study is recommended to identify inland waterway needs for Texas and to evaluate the various alternatives from the state's point of view. The Corps of Engineers has overall responsibility for construction and maintenance of the inland waterway system so detailed plans for improvements to the locks or canals must be prepared by them. However, the state should have an input to a project of such vital concern to Texas. This study should include the following tasks:

(1) Identify commodity flow (origins, destinations, and traffic volumes) of goods entering or leaving Texas on the canal;

(2) Project the increases in transport capacity needed in the next 20 years if economic growth in Texas is not to be stymied;

(3) Evaluate the various alternative solutions in greater detail;

(4) Identify ways to handle increased traffic demands between now and the time that waterway improvements can be accomplished; and

(5) Develop a plan of action for the state relative to waterway improvements.

TRANSPORTATION/LAND USE RELATIONSHIPS

CONCLUSIONS

Recognition of relationships is essential. A recognition of the mutual dependence of urban land use and mode of transportation is essential for proper planning of future urban developments. Rail rapid transit cannot be sustained by single family housing nor can high-rise apartments be served adequately by automobiles alone. Once a city chooses a desired type of land development, it has automatically limited the types of transportation systems that can be used effectively. Unless these constraints are recognized, incompatible urban developments and transportation systems might be selected resulting in high costs and poor service.

Transportation facilities can influence land developments. Land developments within an area can be influenced by the location and design characteristics of transportation facilities serving the area. Arterial streets provide a high level of accessibility that attract commercial developments; however, street design features and access controls can insure that such developments do not destroy the movement function of the arterial. New transportation facilities can stimulate developments in previously undeveloped areas. Land-use and transportation are closely interrelated so that the location and design of new transportation facilities can be used as land-use management tools.

Mass transportation will be needed in some Coastal Zone Cities. If Coastal Zone cities continue to grow around a single focal point, some of them will need mass transportation to support that focal point in the future. For example, the intensity of development in downtown Houston has already exceeded that which can be served by the automobile alone. There appears to be no opportunity for Houston to develop a second focal point to rival the present CBD; therefore, mass transportation will be required to support the additional CBD developments that have already been announced. However, because of the low densities of residential development, it will be extremely difficult to design a mass transportation system that can operate economically in Coastal Zone cities.

RECOMMENDATIONS

Cities should identify preferred urban form. The state has encouraged cities to identify goals and objectives for future growth. This process should include an evaluation of alternative urban forms and a selection of the one preferred by the local areas. The state should encourage each city to include selection of a preferred urban form in their statement of goals and objectives.

Land-use/transportation relationships should be considered. It is recommended that the state require consideration of land-use/transportation relationships in the design and location of all new transportation facilities. Thus, new transportation facilities provided by the state can be effectively used as tools in managing overall land-use.

The state should monitor mass transportation plans. Urban public and mass transportation systems have traditionally been a local responsibility; however, the federal government and the various states are becoming more involved in transit matters. Indeed, some states are now providing sizeable subsidies to keep some mass transportation systems in operation. Texas should monitor all plans for new mass transportation systems because the state might eventually be called upon to subsidize systems that were selected without proper regard for land-use/transportation relationships.

PLANNING AND IMPLEMENTATION PROCEDURES

CONCLUSIONS

Land-use management is needed. Urban areas in the Coastal Zone are expected to experience tremendous growth during the next 30 years. Future transportation problems in these urban areas will largely depend upon how well the various governmental agencies plan new developments and transportation systems; however, even the best plans are of little value if they cannot be implemented. Sound planning and effective land-use management will be required if the net result is to be a pleasant urban environment with a balanced transportation system.

Existing procedures are inadequate. Transportation systems serving some of the urban areas in the Coastal Zone span numerous political jurisdictions (cities and counties); yet, they must function as an integral system. Existing institutional arrangements do not lend themselves to proper planning and implementation of transportation systems serving such areas. The power for land use management is vested in the various cities, and there is no requirement for coordination between cities within the same urban area. Traditional land use controls are not designed to provide the type of land use management needed to shape, or re-shape, urban forms for compatible transportation systems.

RECOMMENDATION

Study of planning procedures is needed. A study is needed to identify and evaluate institutional arrangements and procedures needed for effective transportation planning and implementation. The recommended study should include the following tasks:

(1) Identify transportation planning procedures and land-use management tools currently being used in Coastal Zone areas and evaluate their effectiveness;

(2) Identify and evaluate new procedures and tools that might be used;

(3) Define the advantages and disadvantages that would result if transportation planning and appropriate land use management functions were performed by various levels of government (city, county, council-of-government, state, or others);

(4) Formulate several suitable alternative arrangements for accomplishing effective transportation planning and implementation and evaluate the consequences of each;

(5) Identify the institutional changes that would be necessary under each of the alternatives studied; and

(6) Report results of study to appropriate state and local governments.

TRANSPORTATION CORRIDORS

CONCLUSIONS

Need for transportation is permanent. Transportation corridors connecting major urban areas in the Coastal Zone and other portions of Texas will be needed as long as these activity areas exist. Future transportation facilities serving the need for movement of persons and goods may change drastically with time, but the overall function of the corridor will remain the same. After all, none of the mechanized modes of transportation in use today are much more than 100 years old, but the corridors that they serve are much older.

Lessons from Northeast Corridor are valuable. Experiences in the Northeastern Corridor of the nation have demonstrated the importance of transportation corridors between major urban areas. Also, these experiences have shown that the traffic carrying capacity of such corridors can be seriously limited by land development that tends to occur along them. If positive steps are not taken to protect transportation corridors, the same problems will occur in the Coastal Zone.

RECOMMENDATIONS

Permanent transportation corridor concept should be adopted. Existing surface transportation demands are being served by various highway, railroad, and pipeline facilities located independently so that they probably occupy more total land area than would be necessary in a consolidated transportation corridor. Because land development occurs immediately adjacent to these individual facilities, future increases in capacity will require expensive land acquistion or relocation of routes. Thus, adoption of the permanent transportation corridor concept can result in less total land area being devoted to transportation and still provide greater flexibility for future needs.

Major corridors in Coastal Zone should be defined. A study of transportation corridors within, and radiating from, the Coastal Zone is recommended. This study should include the following tasks:

(1) Identify those major transportation corridors which are in existance today and those which might be needed in the foreseeable future;

(2) Identify existing transportation facilities serving these corridors — their location, right-of-way width, existing capacity, and the volume of traffic being carried by each;

(3) Determine the number of similar type facilities that would be required to handle various multiples of the current traffic volumes, and define the minimum width corridor necessary to serve these various traffic volumes;

(4) Evaluate the alternatives and consequences of various specific corridor locations;

(5) Evaluate various procedures for governmental acquisition of right-of-way and provisions for short-term use of excess land, and identify the legislative changes necessary to permit such actions; and

(6) Develop a plan of action for obtaining and protecting permanent transportation corridors.

ENVIRONMENTAL CONSIDERATIONS

CONCLUSIONS

Environmental effect of transportation are critical in Coastal Zone. The Coastal Zone of Texas contains the most diverse grouping of valuable natural resources in the State, and these resources are particularly susceptible to permanent damage from pollution. The Coastal Zone also contains major elements of every mode of transportation, and they are esential for the economic livelihood of the area. Unfortunately, all modes of transportation must have some impact upon the environment, but steps can be taken to minimize the damaging effects of transportation upon the critical environmental units of the Coastal Zone.

Data are not available on transportation effects. None of the environmental studies conducted to date have tried to compare the relative impact of each mode of transportation based upon an equivalent level of activity. Indeed, it seems that most environmental studies are designed to suit special interest groups. Thus, there is a lack of objective data on the environmental effects of some modes of transportation.

RECOMMENDATIONS

Environmental effects should be considered. All modes of transportation have some impact upon the environment; however, better facility design and improved propulsion systems can reduce the detrimental effects of new transportation systems. The major areas of environmental concern should be given due consideration in the planning process.

Further study is needed. A study of environmental effects of Coastal Zone transportation systems is recommended. This study should include the following tasks:

(1) Survey operating conditions of various Coastal Zone transportation elements;

(2) Evaluate the environmental effects from each mode of transportation;

(3) Identify situations that have a significant impact on critical environmental units along the coast;

(4) Evaluate alternative remedial actions, their effectiveness, and the estimated costs of each; and

(5) Develop a plan of action for minimizing the environmental effects of transportation systems in the Coastal Zone.

RECREATIONAL TRAVEL

CONCLUSIONS

Increases in recreational activities can be expected. The many miles of beaches and numerous bays and estuaries along the Texas coast have tremendous potential for recreational uses. Almost 3 million tourists visited the Gulf Coast of Texas in 1969, and they spent more than 190 million dollars. Yet, the potential for recreational uses of this area have hardly been tapped. The demand, for recreational facilities is expected to increase rapidly in the future because of shorter work weeks and higher average incomes.

Indiscriminate development can be costly. Indiscriminate developments along the coastline, however, can permanently destroy some of the natural attractions of the area. Indeed, the remoteness of Padre Island is one of the main features that attracts campers. Transportation facilities provide the access and accessibility that are necessary for development, therefore, they are the key to effective land-use management along the coast.

RECOMMENDATION

Goals and objectives for Coastal Zone should be established. The state should establish goals and objectives for future development in the Coastal Zone — particularly with regard to recreational uses of beaches, bays, and estuaries. This process should include an identification of those areas that are to be preserved in a relatively undeveloped state. All future transportation facilities should be planned so that they help accomplish these goals and objectives.

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